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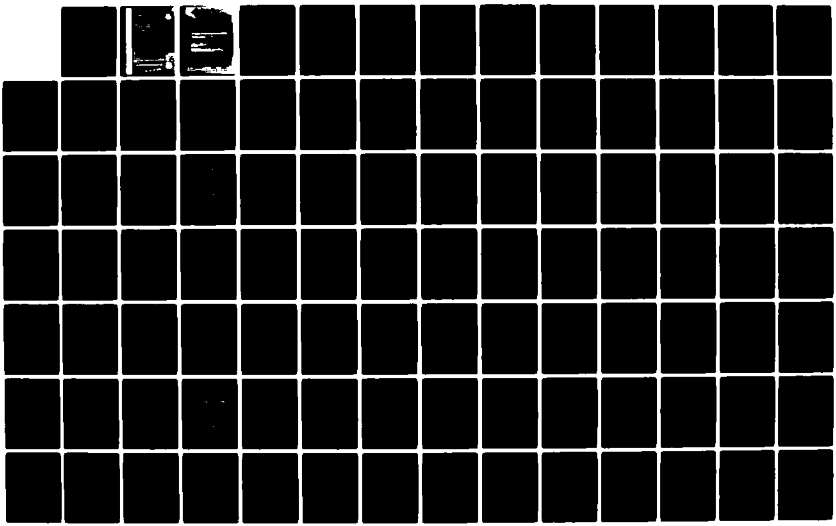

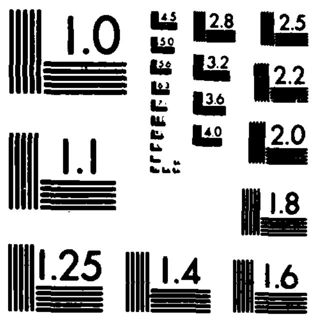

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The results are presented of a study of cloud cover over Korea and Germany, to obtain mesoscale cloud climatologies in data-void regions. Two methods for modeling the climatological frequency distribution of total cloud cover are discussed, a simple linear regression called the Simplified Linear Model (SLM), and Gringorten's Model B. Both models fit the data well. Map analyses of the parameters from both models show definite mesoscale geographic patterns in Korea. This may enable the development of methods for

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20. Abstract (Contd)

obtaining the cloud cover frequency at locations where there are no data. More data are needed to complete such a study. Similar analyses in Germany reveal no obvious geographic relationships for the SLM parameters, and almost no gradient for Model B parameters. The advantage of both models over others is their realistic values for clear and overcast cases. Specific advantages are, for the SLM, its simplicity, and for Model B, its ability to model cloud covers for areas different from that of observer's field of view. The analysis of a previous mesoscale study of visibility indicates that finding mathematical relations between a meteorological variable and mesoscale geophysical features for the purpose of obtaining climatologies in data-void regions is extremely complex. An easier alternative is presented, that of interpolating the model parameters from map analyses.

Contents

Illustrations

Tables

Mesoscale Climatology of Cloud Cover Over Korea and Germany

1. INTRODUCTION

This report details a mesoscale study of total cloud cover over Korea and Germany. The purpose is to identify the influence of mesoscale geographical features, such as topography and nearness to bodies of water on the climatic variations of cloud cover in these regions, in an effort to obtain cloud climatologies in data-void areas. Two models have been developed, each with advantages and disadvantages over the other and over models developed elsewhere.

As a first step in developing a complete mesoscale climatology of total cloud cover, it is convenient to describe the frequency distribution of sky cover by an appropriate mathematical model. The model must be applicable throughout the entire area under study, with only the parameters changing from station to station. As a second step, the model parameters can be analyzed on the mesoscale for patterns related to geographical features. Once these patterns are described, it is possible to find the climatological probability of any fraction of cloud cover for any point in the region in question, provided the necessary geographical information is available.

Several authors have modeled the frequency distribution of sky cover as seen by an observer from the ground. Each model includes all fractions of cloud cover ranging from clear to overcast, and is claimed to have versatile statistical characteristics to simulate J-shaped or U-shaped distributions of sky cover as well as

(Received for publication 18 November 1982)

more conventional bell-shaped distributions. None of the models have been studied, as far as is known, for their variations on the mesoscale. An early popular model is the Beta distribution (Falls[1,2]). Its density function is

$$f(x) = \frac{\Gamma(a+b)}{\Gamma(a)\,\Gamma(b)}\, x^{a-1}(1-x)^{b-1} \qquad a, b > 0 \tag{1}$$

where Γ is the gamma function, x is the fraction of sky covered, and a and b are parameters whose values can vary to permit varying characteristics of the cloud cover distribution. Falls assigned values to a and b in 29 regions of the world. While the density function is easy to compute, the cumulative probability is difficult to obtain since no succinct analytical expression exists. Therefore, tables, numerical integration, or other approximate methods are necessary to obtain cumulative probabilities.

Somerville et al[3] used the Johnson S_B family of distributions to model total cloud cover for seven diverse locations. The S_B family is given by

$$Z = \gamma + \eta\, \ln[x/(1-x)] \quad . \tag{2}$$

The variable x is equal to the fraction of the total cloud cover and the parameters γ and η are determined by the data. The variable Z is the equivalent normal deviate (END) of the cumulative probability of x. Z has a mean of zero and a standard deviation of 1. The solution gives the probability that the cloud cover will be less than or equal to the fractional cover x. Somerville et al developed 96 pairs of values for γ and η for each station (8 times per day, 12 months) using simple linear regression. The root mean square (rms) error for all stations ranged from 0.0175 to 0.0595.

Somerville and Bean[4] developed a cloud model using the S-distribution, which is given by

$$F(x) = 1 - (1 - x^{\alpha})^{\beta} \qquad \alpha, \beta > 0 \quad . \tag{3}$$

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1. Falls, L.W. (1973) The Beta Distribution: A Statistical Model for World Cloud Cover, NASA Technical Memorandum No. 64714, Marshall Space Flight Center, Alabama.

2. Falls, L.W. (1974) The beta distribution: A statistical model for world cloud cover, J. Geophys. Res. 79:1261-1264.

3. Somerville, P.N., Watkins, S., and Daley, R. (1978) Some Models for Sky Cover, Scientific Report No. 2, Contract No. F19628-77-C-0080. Florida Technological University, Orlando, Florida, AFGL-TR-78-0219, AD A062650.

4. Somerville, P.N., and Bean, S.J. (1979) A New Model for Sky Cover, Scientific Report No. 5, Contract No. F19628-77-C-0080. University of Central Florida, Orlando, Florida, AFGL-TR-79-0219, AD A078368.

As in Eqs. (1) and (2), x is equal to the fraction of the total cloud cover, and F(x) is the probability that the cloud cover is less than x. The parameters α and β can be estimated iteratively using the method of maximum likelihood or a nonlinear regression technique. Both methods are considerably more complicated than the simple linear regression used to obtain Eq. (2). Somerville developed 96 different pairs of values for α and β, for 23 stations around the world. The rms errors ranged from 0.003 to 0.071. Strictly speaking, this model, as well as the previously described models, yields zero for the probability of all clear and full overcast; hence they cannot be theoretically accurate. The difficulty is overcome, in practice, by stipulating that the integration for clear be taken from zero to 0.5 tenths, and for overcast from 9.5 to 10 tenths.

There is still another difficulty, which pertains to all of these models. Each solution is given for the sky dome as seen by a ground observer, considered to have a radius of 24 km (15 nm), or an area of 707 nm^2 or 2424 km^2. None of these models give cloud cover frequencies for varying areal coverages.

2. THE MODELS

The two models described here overcome one or both difficulties of the models described above. Each model has its own strong (and weak) points. The first model is a simple linear regression and is hereafter referred to as the simplified linear model (SLM). The SLM is given by

$$Z = ax + b \qquad 0 \le x \le 1 \tag{4}$$

where x is equal to the fraction of the total cloud cover, and Z is the END of the cumulative probability of x. The parameters a and b (slope and y-intercept) are determined by the data. Therefore, as in Eq. (2), the solution yields the probability that the cloud cover will be less than or equal to the fractional cover x. The two parameters have physical meaning. Parameter b is the END of the probability of clear, P (clear), and a + b is the END of 1-P (overcast). A higher value of b indicates a higher probability of clear, and a higher value of parameter a means a steeper slope and thus a lower probability of both clear and overcast, and a higher frequency of a partial cloud cover. The SLM overcomes a weakness of the models previously discussed by yielding finite probabilities of all clear (x = 0) and full overcast (x = 1.0), which, by and large, are the most important estimates of the distribution. The SLM is much simpler than the Beta and S-distribution models, and a bit simpler than the Johnson S_B model in that x does not have to be transformed.

Simple linear regression is used to determine the model parameters a and b after first transforming the cumulative frequencies into ENDs using the approximation[5]

$$Z = k\left[t - \frac{c_o + c_1 t}{1 + d_1 t + d_2 t^2}\right] \tag{5}$$

where, for $P(\le x) \le 0.5$, $k = -1$, $t = \sqrt{\ell n \frac{1}{p^2}}$; for $P(\le x) > 0.5$, $k = 1$, $t = \sqrt{\ell n \frac{1}{(1-p)^2}}$. The expected error of this transformation is ± 0.003 in the END. The constant terms have values $c_o = 2.30753$, $c_1 = 0.27061$, $d_1 = 0.99229$, $d_2 = 0.04481$. When the solution for Z is obtained, it can be transformed into a cumulative probability using the approximation[5]

$$P(x) = k - m\,(1 + C_1|Z| + C_2 Z^2 + C_3|Z|^3 + C_4 Z^4)^{-4} \tag{6}$$

where $C_1 = 0.196854$, $C_2 = 0.115194$, $C_3 = 0.000344$, $C_4 = 0.019527$; for $Z \ge 0$, $k = 1$ and $m = -\frac{1}{2}$, for $Z < 0$, $k = 0$ and $m = \frac{1}{2}$. The expected error is ± 0.00025.

The second model of this report, Model B, has been developed recently by Gringorten[6] for lineal and areal coverage of a *weather element*. Like all the above models, it requires two parameters. Also, like the SLM, the two parameters have physical meaning. One parameter is the mean sky cover (P_o), the other is known as the scale distance (r), where r is the distance between two stations whose correlation coefficient of cloud cover is 0.99. Gringorten has found that this distance varies from 1/2 km to 10 km. There is no succinct mathematical formula for Model B such as Eqs. (1) through (4). Solutions are determined graphically. However, like the SLM, it provides finite probability estimates of all-clear and full overcast, and, unlike any of the previous models, cloud cover can be estimated for varying areal sizes.

P_o is assumed to be the probability of cloud cover over a point on the earth. An observation is limited to either cloud or no cloud. But when the observer is

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5. National Bureau of Standards (1964) Handbook of Mathematical Functions With Formulas, Graphs and Mathematical Tables, Applied Mathematics Series No. 55, Supt. of Documents, U.S. Govt. Printing Office, Washington, D.C.

6. Gringorten, I.I. (1979) Probability models of weather conditions occupying a line or an area, J. Appl. Meteorol. 18:957-977.

asked to estimate areal coverage, then other factors enter into the problem, including the size of the area and the horizontal persistence of the clouds.

Suppose the area of concern is A (km^2). A corresponding linear dimension is given by

$$s' = \sqrt{A} \quad . \tag{7}$$

A standardized non-dimensional measure (s) is given by

$$s = s'/r \tag{8}$$

where r is the scale distance, measured in the same units as s'.

On the graphs [Figures 1(0) to 1(10)] the scale on the horizontal axis is linear in a standardized measure of the area, z, where

$$z = \ln s/\ln 2 = (\ln \sqrt{A}/r)/\ln 2 \quad . \tag{9}$$

The vertical scale on the left of each graph is the cumulative probability; on the right it is the probability of exceedance. Also, on the left, there is a linear scale of y, the END of the probability ($1 - P_o$). The curved lines show the variation of y with areal size z.

For example, one might be concerned with how the probability of all clear varies with increasing area. If, for a given location, the single-point probability of a cloud (P_o) is 0.6, then the probability of a non-intercept, ($1 - P_o$), is equal to 0.4; that is, it has an END of $y = -0.25$. For the area corresponding to $z = 4.0$ the probability of all clear is found on Figure 1(0) by following the END-curve ($y = -0.25$) to its intersection with $z = 4.0$. It reads $P = 0.183$. Consequently, the probability that the entire area is clear is reduced from 40 percent to 18 percent. Similarly, in Figure 1(1) the probability that the cloudiness over the same area is 1/10 or less, is found to be 23 percent. In Figure 1(2) the probability of 2/10 or less cloud cover is 28 percent, and so on. On the last chart [Figure 1(10)] the probability of full overcast is read on the right-hand scale as 36 percent.

As stated earlier, this model, while it is effective with just the two parameters P_o and r, is not accompanied by a simple mathematical formula. Because the graphs are cumbersome and inexact, a computer program is being assembled to yield the probabilities $P(x, A; P_o, r)$, that is, the cumulative probability of the fractional cloud cover (x) within the area (A) when the parameters of mean cloud cover (P_o) and scale distance (r) are known. Another program is being developed to estimate r from climatic tables that give P_o and the cumulative frequencies of partial cover.

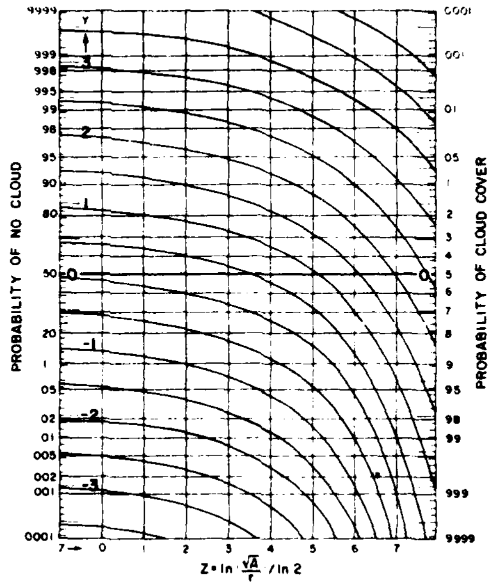

Figure 1(0). x = 0/10

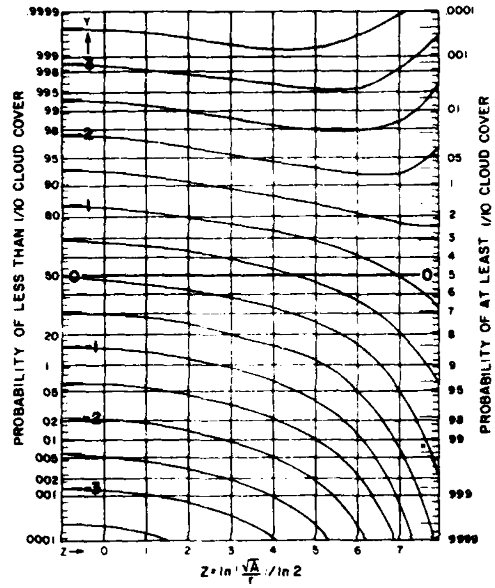

Figure 1(1). x ≤ 1/10

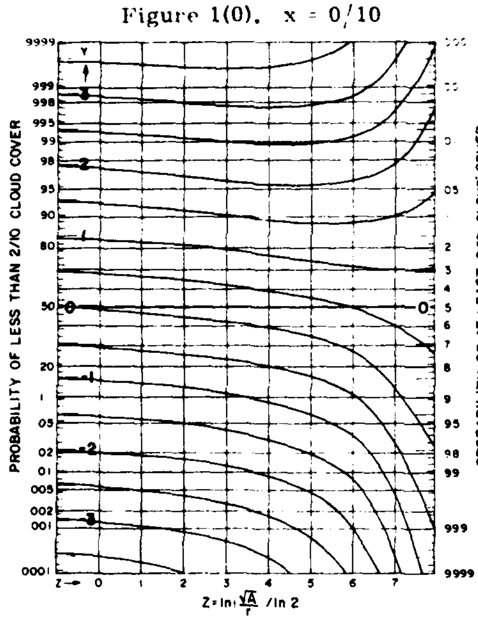

Figure 1(2). x ≤ 2/10

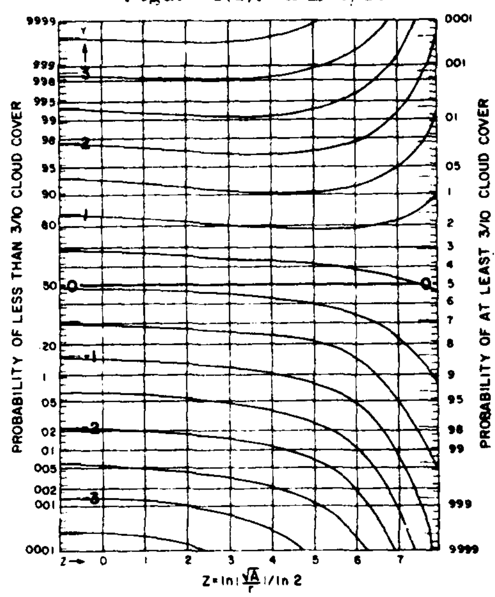

Figure 1(3). x ≤ 3/10

Figure 1. Model B Probability Estimates of Cloud Cover in Values of x in the Area s^2. The horizontal scale is uniform in $z = \ell n\, s/\ell n\, 2$. Instruction: The mean cloud cover, or the single-point probability of cloudiness is found on the probability scale on the right. The complementary probability of single-point no-cloud is read on the left-hand scale. The corresponding y-curve can be followed to its intersection with the z-value of the area s^2. The probability $P_{\infty}(x)$ that the fraction of cloud cover will be less than or equal to x in the area s^2 is read on the left-hand scale

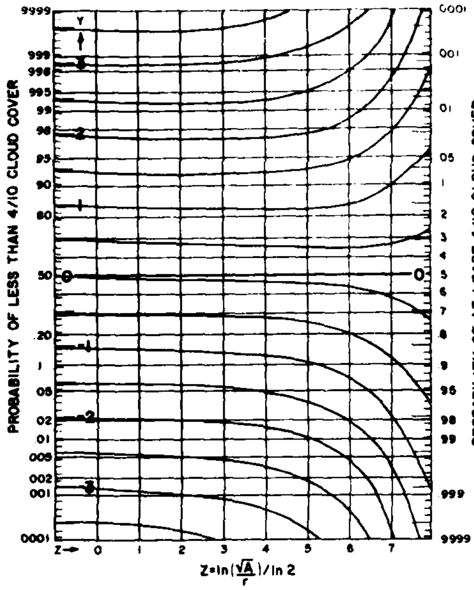

Figure 1(4). $x \leq 4/10$

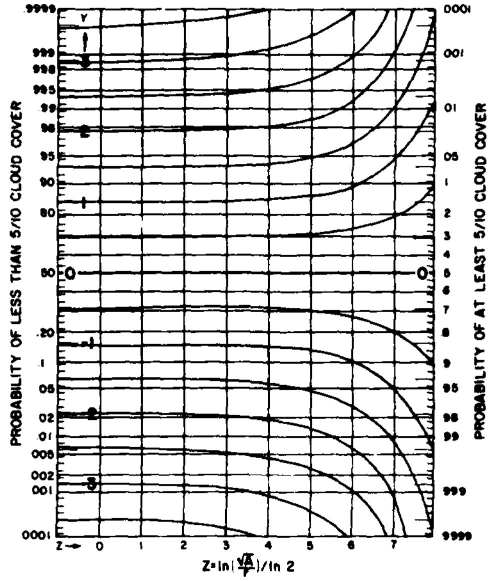

Figure 1(5). $x \leq 5/10$

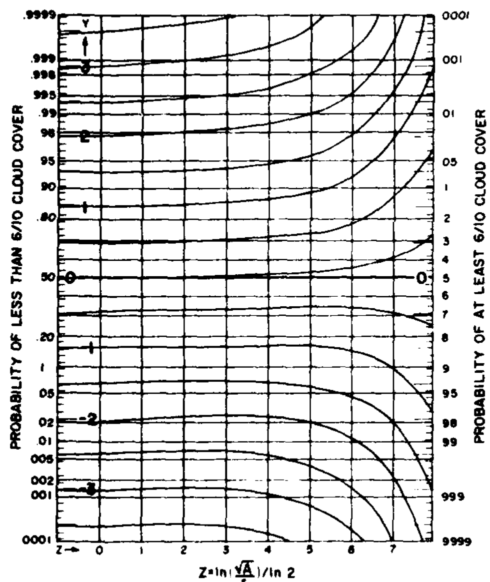

Figure 1(6). $x \leq 6/10$

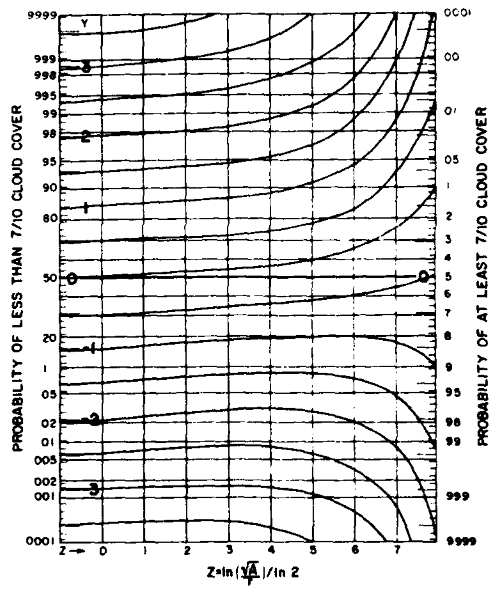

Figure 1(7). $x \leq 7/10$

Figure 1. Model B Probability Estimates of Cloud Cover in Values of x in the Area s^2. The horizontal scale is uniform in $z = \ln s/\ln 2$. Instruction: The mean cloud cover, or the single-point probability of cloudiness is found on the probability scale on the right. The complementary probability of single-point no-cloud is read on the left-hand scale. The corresponding y-curve can be followed to its intersection with the z-value of the area s^2. The probability $P_\infty(x)$ that the fraction of cloud cover will be less than or equal to x in the area s^2 is read on the left-hand scale

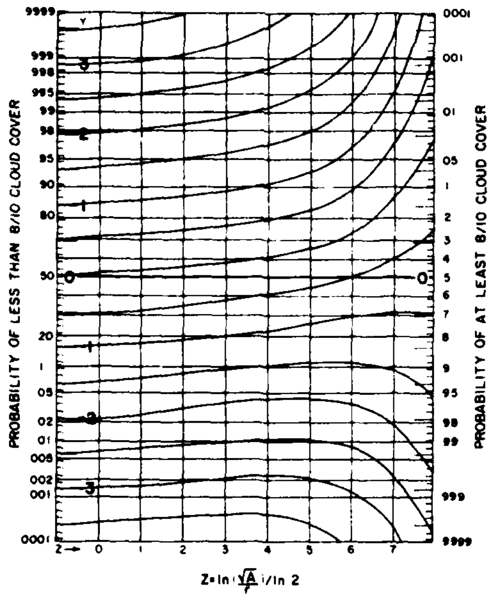

Figure 1(8). $x \leq 8/10$

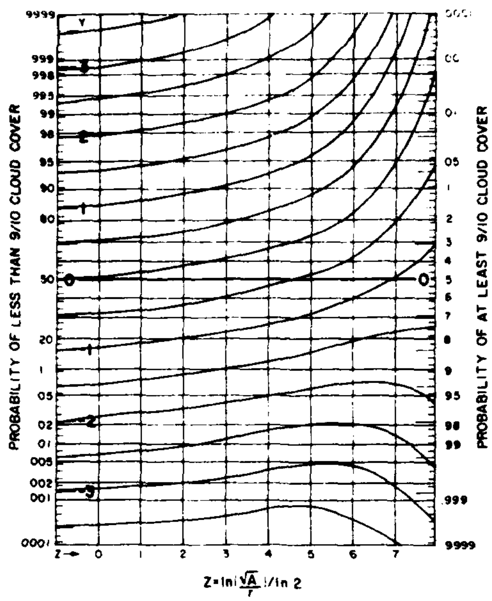

Figure 1(9). $x \leq 9/10$

Figure 1. Model B Probability Estimates of Cloud Cover in Values of x in the Area s^2. The horizontal scale is uniform in $z = \ell n\, s/\ell n\, 2$. Instruction: The mean cloud cover, or the single-point probability of cloudiness is found on the probability scale on the right. The complementary probability of single-point no-cloud is read on the left-hand scale. The corresponding y-curve can be followed to its intersection with the z-value of the area s^2. The probability $P_\infty(x)$ that the fraction of cloud cover will be less than or equal to x in the area s^2 is read on the left-hand scale

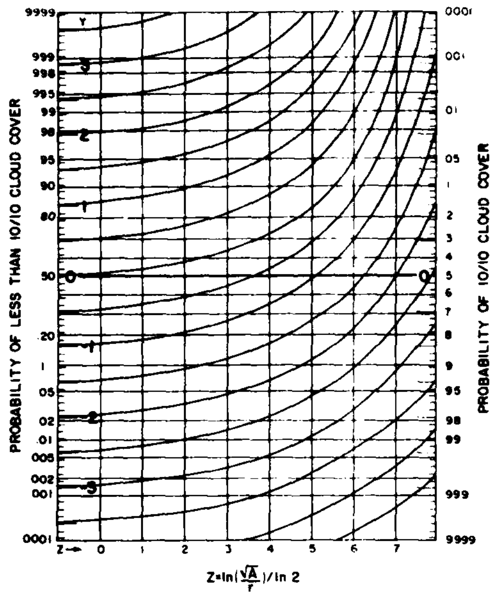

Figure 1(10). Model B Probability Estimates of Full Overcast (x = 10/10) in Area s^2. The single-point probability of cloud cover is found on the right-hand side, and the complementary probability of single-point no-cloud is read on the left-hand side. The corresponding y-curve can be followed till its intersection with the z-value of area s^2. The probability of (10/10) cloud cover in the area s^2 is read on the right-hand scale

The magnitude of r is related to several characteristics of cloudiness. If r is large then it is expected that the sky, climatically speaking, would be either clear or overcast with stratiform clouds, with relatively few days of partial cover. If r is small, then it can be expected that the clouds would be cumuliform, and the individual cloud cells would not be as extensive as stratiform clouds. Thus, r should be small in the summer relative to the winter, smallest at noon, and largest around midnight.

3. MODEL STUDY IN KOREA AND GERMANY

This section gives the results of tests of the SLM and Model B on Korean and German data. Background information on mapping and data sources is also described, as well as an analysis of another study of mesoscale climatology modeling and its application to this report.

3.1 Mapping of Mesoscale Climatology

It is important to map and analyze the mesoscale parameters being studied, as one means of discovering geographic influences. In a recent report,

Gringorten,[7] gave reasons for choosing one map projection over others. For climatology, the azimuthal equal-area projection centered on a selected point of latitude (ϕ_o) and longitude (λ_o) yields the best results. Points are located on the map by finding their Cartesian coordinates (x, y) from their spherical coordinates, latitude ϕ and longitude λ, as follows:

$$\begin{aligned} x &= r \sin A \\ y &= r \cos A \end{aligned} \tag{10}$$

where r and A are given by

$$r = \sqrt{2(1 - \cos \delta)}\ Rs \quad , \tag{11}$$

and

$$\sin A = \frac{\sin (\lambda - \lambda_o)}{\sin \delta} \cos \phi \quad . \tag{12}$$

and, in turn, $\cos \delta = \sin \phi_o \sin \phi + \cos \phi_o \cos \phi \cos (\lambda - \lambda_o)$. In Eq. (11) R is the earth's radius (6334 km) and s is the geometric mean scale of the equal-area map. For a large-scale map, with 1 km represented by 1 cm, $s = 10^{-5}$. For a smaller-scale map, with 100 km represented by 1 cm, $s = 10^{-7}$.

Eq. (12) gives A, *which will be negative when* $\lambda < \lambda_o$. In Eq. (12), if A_c is an acute angle,

$$\begin{aligned} A &= A_c \qquad \text{when} \qquad \phi \geq \phi_s \\ &= (\pi - A_c) \qquad \text{when} \qquad \phi < \phi_s \end{aligned} \tag{13}$$

where ϕ_s *is defined by*

$$\cos \phi_s = \sqrt{\frac{1 - \sin^2 \phi_o}{1 - \sin^2 \phi_o \cdot \sin^2 (\lambda - \lambda_o)}} \quad .$$

The angle $\phi_s \geq 0$ when $\phi_o \geq 0$ and, $\phi_s < 0$ when $\phi_o < 0$.

One area chosen for this mesoscale study is Germany. The map (Figure 2) was drawn on graph paper having 4 divisions to the centimeter. The geographic

7. Gringorten, I.I. (1981) Mapping the Climate, AFGL-TR-81-0015, AD A102904.

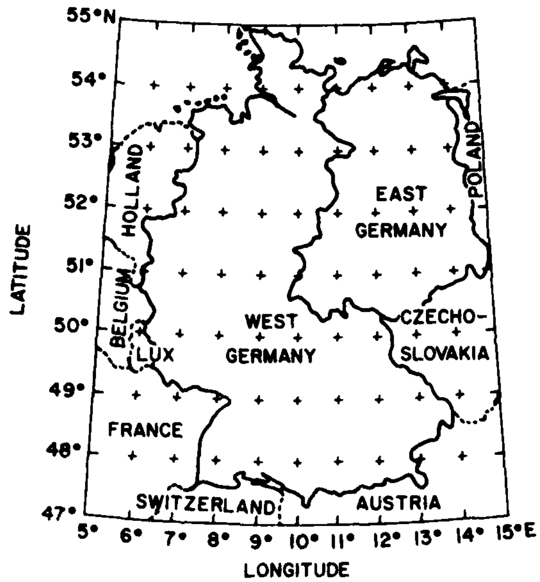

Figure 2. Azimuthal Equal Area Map of Germany Centered on Lat 51°N and Long 10°E

central point was chosen at $\phi_o = 51^\circ N$, $\lambda_o = 10^\circ E$. The north-south extent of Germany, approximately 890 km, is drawn on the map within 18 cm. The scale s, therefore is

$$s = 18 \times 10^{-2}/890 \times 10^{3} = 2.0 \times 10^{-7} \quad .$$

The first points to be plotted are the intersections of the meridians and parallels at 1° intervals. The political boundaries can then be plotted by eye by comparing them with the boundaries from another projection, or by a succession of pairs of coordinates outlining the country, streams or other bodies of water. A similar map was constructed for Korea.

Gringorten has outlined a step-by-step procedure for programming the equations to find each pair of Cartesian coordinates (x, y) corresponding to each pair of geographic coordinates (ϕ, λ). At any point of the map, information can be plotted for details in their own right, or for further analysis and the drawing of isopleths.

3.2 Data Sources

The Revised Uniform Summaries of Surface Weather Observations (RUSSWO) developed by the USAF Environmental Technical Applications Center, were the main source of our climatology of sky cover. Figure 3 is an example for Chinhae, South Korea, in January. The observations are grouped into eight 3-h time periods, given in Local Standard Time (LST), starting with 00-02 LST and ending with 21-23 LST. Observations of total sky cover are reported in tenths, from clear to overcast. Hence, Figure 3 shows the percentage frequency of each tenth. This value represents an average of the three hourly frequencies. Several stations reported sky cover in octas. For input to SLM and Model B, the data had to be converted into cumulative frequencies. It was assumed that the categories of tenths (or octas) represent equal intervals that cover the entire spectrum from clear to overcast. In the case of tenths, 0 tenths includes all cases from 0 to 0.5 tenths. One tenth includes all cases from 0.5 tenths to 1.5 tenths, and so on. Lastly, 10 tenths includes all cases from 9.5 tenths to 10 tenths. As an example, Table 1 shows the cumulative frequencies as calculated from Figure 3 for Chinhae, South Korea, in Jan, for 21-23 LST. A similar conversion was made for those stations reporting in octas. In addition to the eleven columns for the percent frequency of each category of sky cover there is a column for the mean sky cover in tenths, that is, P_o of Model B.

Other sources of information were used occasionally, especially that of the National Intelligence Survey (NIS) Section 23, Weather and Climate. These tabulations most frequently present tables of P_o at several hours of the day, and the frequency of cloud cover equal to or less than 2/8 and equal to or more than 6/8. Some countries' records are given in tenths.

For this research, the data were selected for the mid-season months of January, April, July and October for the time intervals 00-02, 06-08, 12-14, and 18-20 LST. A complete list of the stations used in the study along with their latitude, longitude, and elevation is given in Tables 2 and 3 for Korea and Germany respectively. Because of poor or missing records for many of the stations, not all stations were used in each phase of the study. For instance, none of the NIS data could be used in testing the SLM because of their incomplete record of the frequency of sky cover. In most cases, only stations with 10 years or more of data were used. Data usage in different parts of the experiments is described in the appropriate sections of the report.

DATA PROCESSING DIVISION
ETAC, USAF
ASHEVILLE, N.C. 28801

SKY COVER

43208 CHINHAE KOREA/ROK AFS K-10 — 51-54, 56-61, 64-67 — JAN
STATION — STATION NAME — PERIOD — MONTH

PERCENTAGE FREQUENCY OF OCCURRENCE
(FROM HOURLY OBSERVATIONS)

MONTH	HOURS (L S T)	PERCENTAGE FREQUENCY OF TENTHS OF TOTAL SKY COVER											MEAN TENTHS OF SKY COVER	TOTAL NO. OF OBS
		0	1	2	3	4	5	6	7	8	9	10		
JAN	00-02	57.3	3.6	3.1	1.9	2.6	1.9	1.3	3.0	4.2	1.8	20.0	3.1	908
	03-05	58.2	1.7	3.4	3.0	2.1	2.5	2.8	3.3	2.0	1.5	19.4	3.0	1033
	06-08	46.5	3.6	4.6	2.5	4.1	2.8	2.7	3.6	4.3	3.0	22.6	3.8	1281
	09-11	45.3	4.4	4.1	3.7	2.7	2.9	2.2	2.7	4.4	3.2	24.5	3.9	1281
	12-14	42.3	4.5	3.9	4.1	3.6	2.8	2.5	3.4	5.2	2.9	24.8	4.1	1281
	15-17	43.5	5.5	5.0	4.5	3.1	2.8	3.1	2.5	3.8	2.2	24.0	3.8	1278
	18-20	51.4	5.5	5.1	4.7	3.9	1.8	1.7	2.9	3.1	1.0	21.1	3.2	909
	21-23	57.8	1.3	5.3	3.4	1.4	1.7	2.4	3.4	3.7	1.4	18.2	3.0	909
TOTALS		49.4	3.8	4.3	3.5	2.8	2.5	2.4	3.1	3.9	2.2	22.2	3.6	8880

Figure 3. RUSSWO Data for Chinhae, South Korea, in January

Table 1. Cumulative Frequency of Total Sky Cover for Chinhae, South Korea, in Jan, for 21-23 LST (From Figure 3)

x (tenths)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5
P (≤x)	0.578	0.591	0.644	0.678	0.692	0.709	0.733	0.767	0.804	0.818

Table 2. Korean Stations Used in the Study

	Station	Lat (°N)	Long (°E)	Elev (m)
1.	Chinhae	35°8'	128°42'	5
2.	Chunchon	37°52'	127°43'	76
3.	Hoengsong	37°27'	127°57'	100
4.	Kangnung	37°45'	128°56'	27
5.	Kunsan	35°55'	126°37'	10
6.	Kwandae-Ri	38°1'	128°8'	180
7.	Mosulp-O	33°12'	126°13'	6
8.	Osan-Ni	37°6'	127°2'	13
9.	Paengnyong Do	37°59'	124°40'	95
10.	Pusan East	35°10'	129°8'	5
11.	Pyongtaek	36°57'	127°0'	16
12.	Sachon	35°5'	128°5'	8
13.	Seoul	37°34'	126°56'	22
14.	Taegu	35°54'	128°39'	30
15.	Taejon	36°20'	127°23'	40
16.	Uijungbu	37°44'	127°2'	53
17.	Tonggo Ri	37°47'	126°51'	24
18.	Tongduchon	37°56'	127°3'	60
19.	Hamhung	39°54'	127°31'	33
20.	Haeju	38°2'	125°42'	81
21.	Inchon	37°29'	126°38'	70
22.	Kaesong	37°58'	126°33'	137
23.	Pyongyang	39°1'	125°49'	29
24.	Changgi-Ap	36°5'	129°34'	21
25.	Wonsan	39°11'	127°26'	30
26.	Kwangju	35°7'	126°49'	13

Table 3. German Stations Used in the Study

	Station	Lat (°N)	Long (°E)	Elev (m)
1.	Heidelberg	49°24'	8°39'	112
2.	Stuttgart	48°41'	9°12'	395
3.	Bitburg	49°57'	6°34'	374
4.	Bad Kreuznach	49°52'	7°53'	108
5.	Wiesbaden	50°3'	8°20'	143
6.	Spangdahlem	49°58'	6°42'	365
7.	Hahn	49°57'	7°16'	503
8.	Sembach	49°31'	7°52'	321
9.	Zweibrücken	49°13'	7°24'	345
10.	Sandhofen	49°34'	8°28'	99
11.	Erding	48°19'	11°56'	464
12.	Nürnberg	49°30'	11°5'	321
13.	Grafenwöhr	49°42'	11°57'	418
14.	Kitzingen	49°45'	10°12'	213
15.	Hanau	50°10'	8°57'	115
16.	Rhein-Main	50°2'	8°35'	112
17.	Fulda	50°32'	9°38'	308
18.	Berlin	52°28'	13°26'	50
19.	Illesheim	49°28'	10°23'	313
20.	Ramstein	49°26'	7°36'	237
21.	Schwäbish	49°7'	9°47'	395
22.	Finten	49°58'	8°9'	224
23.	Baumholder	49°39'	7°18'	428
24.	Ketterbach	49°19'	10°38'	467
25.	Fürth	49°30'	10°57'	397
26.	Hohenfels	49°13'	11°50'	445
27.	Gablingen	48°27'	10°52'	466
28.	Bad Tölz	47°46'	11°36'	719
29.	Boizenburg	53°23'	10°43'	46
30.	Cottbus	51°46'	14°20'	74
31.	Frankfurt	52°20'	14°35'	57
32.	Gardelegen	52°32'	11°24'	46

Table 3. German Stations Used in the Study (Contd)

Station		Lat (°N)	Long (°E)	Elev (m)
33.	Görlitz	51°10'	15°0'	217
34.	Kröllwitz	51°31'	11°57'	115
35.	Neustrelitz	53°22'	13°4'	75
36.	Potsdam	52°23'	13°4'	82
37.	Schönefeld	52°22'	13°31'	54
38.	Ueckermünde	53°45'	14°4'	7
39.	Wahnsdorf	51°7'	13°41'	257
40.	Weimar	50°59'	11°19'	268
41.	Wieck	54°6'	13°27'	3
42.	Wismar	53°54'	11°27'	30
43.	Wittenberg	51°53'	12°39'	107
44.	Wittenberge	53°2'	11°48'	26
45.	Brocken	51°48'	10°37'	1150
46.	Chemnitz	50°50'	12°55'	321
47.	Fichtel-Berg	50°26'	12°57'	1220
48.	Gross Inselsberg	50°51'	10°28'	906
49.	Plauen	50°30'	12°8'	381
50.	Sonneberg	50°23'	11°11'	630
51.	Warnemünde	54°11'	12°5'	13
52.	Kaltennordheim	50°39'	10°9'	494
53.	München	48°8'	11°42'	528
54.	Freiburg	48°0'	7°51'	286
55.	Magdeburg	52°8'	11°34'	45
56.	Emden	53°22'	7°13'	1
57.	Hamburg	53°38'	10°0'	18
58.	Münster	51°58'	7°36'	90
59.	Hannover	52°28'	9°45'	51
60.	Köln/Bohn	50°52'	7°9'	48
61.	Schleswig	54°32'	9°33'	48
62.	Kassel	51°20'	9°27'	198
63.	Dresden	51°7'	13°41'	257
64.	Würzburg	49°48'	9°54'	260

3.3 Model Study in Korea

This section of the report presents and analyzes the results of the application of the SLM and Model B to the Korean data.

3.3.1 THE SLM IN KOREA

Model parameters a and b were calculated for the South Korean stations numbered 1-18 in Table 2 for all specified times and months except for Tonggo-Ri and Tongduchon, which only had data available for the 06-08 and 12-14 LST time periods. These stations are located geographically in Figure 4a. The parameter values, along with the linear correlation coefficients (ρ), explained variations, and rms errors, are shown in Tables 4(1)-(18). The explained variation is equal to ρ^2 and, in this case, is the fraction of the variation of Z explained by the regression equation (Wonnacott and Wonnacott[8]). Therefore, it indicates the value of the regression equation in reducing the variation in Z. If the data were a straight line, then ρ^2 would be 1, and if there were no linear relationship at all, ρ^2 would be 0. Table 4 shows that for all stations and time periods, ρ^2 of Z ranges from 0.955 to 0.998, or, that the percentage variation left unexplained by the regression equation ranges from 0.2 to 4.5 percent. Station averages for ρ^2 range from 0.982 to 0.992, and the overall mean is 0.988. Thus, the model equations give an excellent fit. This is also shown by the rms errors, which were calculated after the END values were converted back to the cumulative frequencies. These values range from 0.004 to 0.025 for all stations and time periods, with a station average range of 0.009 to 0.015 and an overall mean of 0.012. Examples of a "worst-fit" case, an "average-fit" case, and a "best-fit" case are shown graphically in Figure 5. The worst case is Chinhae in July for 12-14 LST with a ρ^2 of 0.955 and an rms error of 0.022. The average case is Kangnung in Jan for 18-20 LST, with a ρ^2 of 0.988 and an rms error of 0.012. The best case is Chunchon in Jan for 18-20 LST with a ρ^2 of 0.998 and an rms error of 0.005. The lines in the figure are the model fits and the data are marked by the X's, crosses, and dots, respectively, for the worst, average, and best cases. Note that in the "best-fit" case the difference between the model and data values cannot be distinguished on the graph. These three cases are also shown in tabular form in Tables 5a-5c. The differences in observed and model cumulative frequencies range from 0.1 to 3.6 percent (absolute values). The model frequency lies above and below the observed frequency about equally.

Figures 6a-6p show the subjective analyses of model parameter a, and Figures 7a-7p the subjective analyses of parameter b for all time periods.

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8. Wonnacott, T.H., and Wonnacott, R.J. (1972) Introductory Statistics, John Wiley & Sons, Inc., New York, pp 336-342.

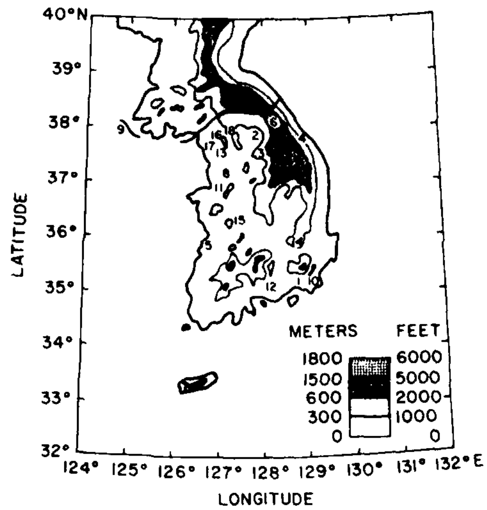

Figure 4a. Locations of the Korean Stations Used in the Simplified Linear Model Study. Station identifiers correspond to the numbers in Table 2

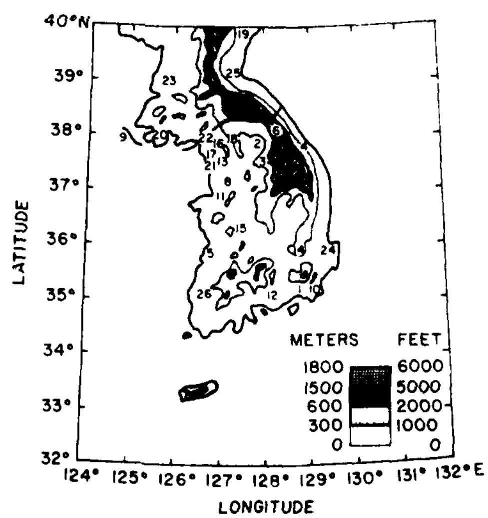

Figure 4b. Locations of the Korean Stations Used in the Model B Study. Station identifiers correspond to the numbers in Table 2

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study

4(1) Chinhae

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.694	0.147	0.993	0.986	0.008
	06-08	0.905	-0.131	0.998	0.996	0.006
	12-14	0.925	-0.223	0.997	0.994	0.008
	18-20	0.808	0.072	0.984	0.968	0.015
April	00-02	0.733	-0.316	0.991	0.982	0.011
	06-08	0.893	-0.769	0.996	0.992	0.008
	12-14	1.100	-0.962	0.999	0.998	0.005
	18-20	1.101	-0.700	0.998	0.996	0.007
July	00-02	0.832	-0.966	0.998	0.996	0.005
	06-08	1.296	-1.648	0.990	0.980	0.016
	12-14	1.697	-1.676	0.977	0.955	0.022
	18-20	1.507	-1.464	0.993	0.986	0.014
October	00-02	0.750	0.131	0.994	0.988	0.008
	06-08	1.065	-0.384	0.991	0.982	0.016
	12-14	1.459	-0.773	0.997	0.994	0.012
	18-20	0.956	-0.194	0.997	0.994	0.009
Average				0.993	0.986	0.011

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(2) Chunchon						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.662	-0.005	0.988	0.976	0.011
	06-08	0.670	-0.092	0.995	0.990	0.007
	12-14	0.909	-0.243	0.998	0.996	0.007
	18-20	0.973	-0.243	0.999	0.998	0.005
April	00-02	0.792	0.005	0.991	0.982	0.012
	06-08	0.867	-0.683	0.992	0.984	0.012
	12-14	1.174	-0.994	0.996	0.992	0.011
	18-20	1.256	-0.907	0.998	0.996	0.009
July	00-02	1.342	-1.159	0.996	0.992	0.012
	06-08	1.436	-1.859	0.996	0.992	0.009
	12-14	2.097	-2.059	0.994	0.988	0.013
	18-20	1.978	-1.853	0.997	0.994	0.012
October	00-02	0.534	0.272	0.984	0.968	0.010
	06-08	1.033	-0.971	0.997	0.994	0.009
	12-14	1.338	-0.622	0.996	0.992	0.013
	18-20	1.095	-0.283	0.987	0.974	0.020
Average				0.994	0.988	0.011

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(3) Hoengsong

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.747	-0.042	0.995	0.990	0.008
	06-08	0.736	-0.170	0.994	0.988	0.009
	12-14	0.992	-0.354	0.998	0.996	0.006
	18-20	0.909	-0.243	0.997	0.994	0.007
April	00-02	0.733	-0.309	0.995	0.990	0.008
	06-08	0.919	-0.708	0.998	0.996	0.007
	12-14	1.337	-1.069	0.998	0.996	0.009
	18-20	1.278	-0.979	0.998	0.996	0.008
July	00-02	1.023	-0.961	0.996	0.992	0.009
	06-08	1.427	-1.777	0.991	0.982	0.016
	12-14	2.317	-2.164	0.995	0.990	0.013
	18-20	1.978	-1.766	0.995	0.990	0.014
October	00-02	0.987	-0.051	0.996	0.992	0.009
	06-08	1.057	-0.504	0.995	0.990	0.011
	12-14	1.466	-0.655	0.996	0.992	0.013
	18-20	1.397	-0.476	0.998	0.996	0.010
Average				0.996	0.992	0.010

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(4) Kangnung						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.747	0.179	0.995	0.990	0.008
	06-08	0.914	0.064	0.993	0.986	0.012
	12-14	1.037	-0.208	0.994	0.988	0.013
	18-20	0.980	-0.103	0.994	0.988	0.012
April	00-02	0.793	-0.299	0.998	0.996	0.006
	06-08	0.918	-0.669	0.995	0.990	0.010
	12-14	1.103	-0.928	0.993	0.986	0.013
	18-20	1.101	-0.914	0.997	0.994	0.009
July	00-02	0.971	-0.959	0.995	0.990	0.010
	06-08	1.116	-1.431	0.989	0.978	0.015
	12-14	1.595	-1.621	0.993	0.986	0.015
	18-20	1.468	-1.572	0.990	0.980	0.016
October	00-02	0.809	-0.060	0.998	0.996	0.005
	06-08	1.040	-0.374	0.994	0.988	0.012
	12-14	1.262	-0.642	0.996	0.992	0.012
	18-20	1.047	-0.505	0.995	0.990	0.012
Average				0.994	0.988	0.011

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(5) Kunsan

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.118	-0.863	0.995	0.990	0.012
	06-08	1.443	-1.115	0.992	0.984	0.016
	12-14	1.346	-0.946	0.996	0.992	0.012
	18-20	1.320	-0.922	0.995	0.990	0.013
April	00-02	0.803	-0.440	0.997	0.994	0.007
	06-08	0.947	-0.886	0.994	0.988	0.011
	12-14	1.054	-0.902	0.985	0.970	0.018
	18-20	1.047	-0.796	0.992	0.984	0.013
July	00-02	1.182	-1.126	0.997	0.994	0.009
	06-08	1.904	-2.012	0.993	0.986	0.018
	12-14	2.167	-1.958	0.987	0.974	0.022
	18-20	1.888	-1.721	0.991	0.982	0.023
October	00-02	1.107	-0.258	0.997	0.994	0.010
	06-08	1.601	-0.726	0.994	0.988	0.019
	12-14	1.554	-0.691	0.991	0.982	0.022
	18-20	1.255	-0.377	0.995	0.990	0.016
Average				0.993	0.986	0.015

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(6) Kwandae Ri						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.454	-0.132	0.977	0.994	0.011
	06-08	0.531	-0.015	0.988	0.996	0.009
	12-14	0.813	-0.217	0.994	0.988	0.010
	18-20	0.740	-0.192	0.996	0.992	0.008
April	00-02	0.786	0.132	0.987	0.974	0.014
	06-08	0.699	-0.575	0.997	0.994	0.006
	12-14	0.974	-0.771	0.995	0.990	0.011
	18-20	1.029	-0.765	0.998	0.996	0.007
July	00-02	1.482	-1.316	0.992	0.984	0.018
	06-08	1.304	-1.767	0.996	0.992	0.007
	12-14	1.617	-1.678	0.996	0.992	0.014
	18-20	1.734	-1.687	0.998	0.996	0.010
October	00-02	0.559	0.215	0.987	0.974	0.010
	06-08	0.871	-0.919	0.996	0.992	0.008
	12-14	1.222	-0.457	0.998	0.996	0.008
	18-20	1.043	-0.263	0.993	0.986	0.014
Average				0.994	0.988	0.010

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(7) Mosulp-O						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.173	-1.246	0.997	0.994	0.009
	06-08	1.568	-1.641	0.993	0.986	0.013
	12-14	1.699	-1.787	0.991	0.982	0.021
	18-20	1.378	-1.445	0.996	0.992	0.010
April	00-02	0.817	-0.808	0.997	0.994	0.007
	06-08	1.001	-1.111	0.996	0.992	0.008
	12-14	1.051	-1.200	0.996	0.992	0.010
	18-20	1.051	-1.057	0.994	0.988	0.011
July	00-02	1.145	-1.275	0.995	0.990	0.008
	06-08	1.637	-1.797	0.993	0.986	0.012
	12-14	2.067	-1.972	0.990	0.980	0.017
	18-20	1.777	-1.712	0.980	0.960	0.025
October	00-02	1.052	-0.302	0.999	0.998	0.006
	06-08	1.731	-0.873	0.990	0.980	0.024
	12-14	1.824	-0.976	0.992	0.984	0.022
	18-20	1.425	-0.626	0.993	0.986	0.018
Average				0.993	0.986	0.014

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(8) Osan-Ni						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.798	-0.168	0.996	0.992	0.008
	06-08	0.894	-0.342	0.989	0.978	0.014
	12-14	1.049	-0.440	0.991	0.982	0.015
	18-20	1.016	-0.265	0.995	0.990	0.010
April	00-02	0.685	-0.368	0.998	0.996	0.005
	06-08	0.958	-0.856	0.998	0.996	0.006
	12-14	1.097	-0.954	0.993	0.986	0.012
	18-20	1.017	-0.735	0.992	0.984	0.013
July	00-02	1.079	-1.220	0.994	0.988	0.010
	06-08	1.524	-1.978	0.992	0.984	0.015
	12-14	2.151	-2.178	0.997	0.994	0.013
	18-20	1.700	-1.588	0.987	0.974	0.020
October	00-02	0.877	-0.089	0.998	0.996	0.006
	06-08	1.322	-0.619	0.993	0.986	0.017
	12-14	1.440	-0.777	0.997	0.994	0.011
	18-20	1.046	-0.229	0.996	0.992	0.011
Average				0.994	0.988	0.012

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(9) Paengnyong Do						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.226	-0.885	0.992	0.984	0.017
	06-08	1.491	-1.185	0.994	0.988	0.017
	12-14	1.540	-1.271	0.991	0.982	0.022
	18-20	1.409	-1.073	0.995	0.990	0.016
April	00-02	0.619	-0.234	0.998	0.996	0.005
	06-08	0.931	-0.762	0.998	0.996	0.007
	12-14	0.792	-0.632	0.992	0.984	0.012
	18-20	0.914	-0.648	0.997	0.994	0.008
July	00-02	0.766	-1.100	0.998	0.996	0.004
	06-08	1.219	-1.735	0.997	0.994	0.006
	12-14	1.532	-1.639	0.995	0.990	0.013
	18-20	1.312	-1.468	0.995	0.990	0.009
October	00-02	1.067	-0.262	0.998	0.996	0.008
	06-08	1.476	-0.692	0.995	0.990	0.015
	12-14	1.599	-0.796	0.994	0.988	0.019
	18-20	1.152	-0.397	0.996	0.992	0.010
Average				0.995	0.990	0.012

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(10) Pusan East

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.723	0.142	0.992	0.984	0.009
	06-08	1.050	-0.223	0.996	0.992	0.011
	12-14	0.931	-0.252	0.996	0.992	0.009
	18-20	0.794	0.123	0.990	0.980	0.012
April	00-02	0.687	-0.287	0.996	0.992	0.007
	06-08	0.890	-0.672	0.990	0.980	0.015
	12-14	1.088	-0.882	0.996	0.992	0.010
	18-20	1.104	-0.781	0.999	0.998	0.006
July	00-02	0.723	-0.807	0.994	0.988	0.008
	06-08	1.274	-1.492	0.996	0.992	0.011
	12-14	1.548	-1.529	0.989	0.978	0.022
	18-20	1.451	-1.398	0.995	0.990	0.012
October	00-02	0.837	-0.082	0.996	0.992	0.009
	06-08	1.172	-0.496	0.988	0.976	0.020
	12-14	1.646	-0.899	0.998	0.996	0.011
	18-20	1.164	-0.431	0.995	0.990	0.013
Average				0.994	0.988	0.012

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(11) Pyongtaek						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.870	-0.298	0.995	0.990	0.010
	06-08	0.893	-0.366	0.993	0.986	0.012
	12-14	1.094	-0.546	0.996	0.992	0.011
	18-20	1.023	-0.311	0.994	0.988	0.012
April	00-02	0.818	-0.277	0.996	0.992	0.009
	06-08	0.926	-0.863	0.997	0.994	0.008
	12-14	1.181	-1.017	0.995	0.990	0.013
	18-20	1.032	-0.461	0.994	0.988	0.013
July	00-02	1.224	-1.133	0.997	0.994	0.009
	06-08	1.744	-2.014	0.991	0.982	0.019
	12-14	2.252	-2.208	0.999	0.998	0.008
	18-20	1.884	-1.599	0.995	0.990	0.017
October	00-02	0.843	-0.006	0.993	0.986	0.010
	06-08	1.204	-0.562	0.998	0.996	0.009
	12-14	1.425	-0.750	0.997	0.994	0.012
	18-20	1.121	-0.058	0.980	0.960	0.024
Average				0.994	0.988	0.012

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(12) Sachon						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.944	0.182	0.998	0.996	0.006
	06-08	1.131	-0.054	0.996	0.992	0.011
	12-14	1.296	-0.320	0.998	0.996	0.009
	18-20	1.287	-0.174	0.992	0.984	0.017
April	00-02	0.873	-0.562	0.998	0.996	0.006
	06-08	0.871	-0.747	0.996	0.992	0.009
	12-14	1.182	-0.969	0.996	0.992	0.011
	18-20	1.238	-1.029	0.998	0.996	0.009
July	00-02	1.180	-1.016	0.996	0.992	0.010
	06-08	1.644	-1.811	0.997	0.994	0.009
	12-14	2.203	-2.022	0.990	0.980	0.020
	18-20	2.061	-1.776	0.991	0.982	0.017
October	00-02	0.894	-0.002	0.997	0.994	0.007
	06-08	1.281	-0.378	0.992	0.984	0.015
	12-14	1.520	-0.602	0.997	0.994	0.013
	18-20	1.419	-0.542	0.993	0.986	0.017
Average				0.995	0.990	0.012

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(13) Seoul						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.692	0.001	0.996	0.992	0.007
	06-08	0.838	-0.262	0.992	0.984	0.012
	12-14	1.034	-0.373	0.996	0.992	0.010
	18-20	0.966	-0.142	0.992	0.984	0.013
April	00-02	0.724	-0.308	0.998	0.996	0.006
	06-08	1.018	-0.807	0.996	0.992	0.010
	12-14	1.249	-0.941	0.994	0.988	0.013
	18-20	1.147	-0.657	0.993	0.986	0.014
July	00-02	1.061	-1.203	0.998	0.996	0.005
	06-08	1.489	-1.844	0.985	0.970	0.020
	12-14	2.334	-2.184	0.997	0.994	0.016
	18-20	1.717	-1.544	0.989	0.978	0.019
October	00-02	0.927	-0.067	0.997	0.994	0.008
	06-08	1.308	-0.664	0.988	0.976	0.022
	12-14	1.559	-0.729	0.997	0.994	0.013
	18-20	1.178	-0.197	0.994	0.988	0.015
Average				0.994	0.988	0.013

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(14) Taegu						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.914	-0.055	0.998	0.996	0.007
	06-08	1.133	-0.343	0.991	0.982	0.017
	12-14	1.056	-0.333	0.995	0.990	0.012
	18-20	0.962	-0.051	0.989	0.978	0.016
April	00-02	0.734	-0.400	0.998	0.996	0.005
	06-08	0.946	-0.831	0.993	0.986	0.012
	12-14	1.225	-1.022	0.997	0.994	0.010
	18-20	1.095	-0.850	0.994	0.988	0.013
July	00-02	1.134	-1.007	0.997	0.994	0.010
	06-08	1.594	-1.682	0.994	0.988	0.017
	12-14	2.522	-2.257	0.990	0.980	0.020
	18-20	1.894	-1.710	0.994	0.988	0.016
October	00-02	0.919	-0.083	0.998	0.996	0.006
	06-08	1.260	-0.552	0.992	0.984	0.018
	12-14	1.612	-0.844	0.994	0.988	0.019
	18-20	1.133	-0.369	0.996	0.992	0.012
Average				0.994	0.988	0.013

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(15) Taejon						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.023	-0.259	0.993	0.986	0.014
	06-08	1.045	-0.526	0.998	0.996	0.008
	12-14	1.210	-0.670	0.996	0.992	0.013
	18-20	1.158	-0.428	0.994	0.988	0.015
April	00-02	0.695	-0.308	0.993	0.986	0.010
	06-08	0.967	-0.772	0.996	0.992	0.010
	12-14	1.224	-0.962	0.998	0.996	0.010
	18-20	1.074	-0.323	0.996	0.992	0.011
July	00-02	1.311	-1.132	0.997	0.994	0.009
	06-08	1.628	-1.904	0.993	0.986	0.017
	12-14	2.413	-2.214	0.998	0.996	0.010
	18-20	1.708	-1.625	0.994	0.988	0.012
October	00-02	0.992	-0.057	0.997	0.994	0.008
	06-08	1.340	-0.716	0.994	0.988	0.016
	12-14	1.607	-0.833	0.999	0.998	0.008
	18-20	1.127	-0.355	0.995	0.990	0.012
Average				0.996	0.992	0.011

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(16) Uijongbu						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.687	0.032	0.995	0.990	0.008
	06-08	0.683	-0.098	0.992	0.984	0.010
	12-14	0.950	-0.377	0.995	0.990	0.011
	18-20	0.[illegible]24	-0.013	0.996	0.992	0.008
April	00-02	0.561	-0.165	0.998	0.996	0.004
	06-08	0.908	-0.764	0.995	0.990	0.010
	12-14	1.106	-1.003	0.997	0.994	0.008
	18-20	1.006	-0.633	0.995	0.990	0.011
July	00-02	0.885	-1.049	0.997	0.994	0.007
	06-08	1.257	-1.745	0.993	0.986	0.011
	12-14	2.298	-2.345	0.999	0.998	0.008
	18-20	1.505	-1.460	0.995	0.990	0.013
October	00-02	0.729	0.099	0.998	0.996	0.005
	06-08	1.058	-0.454	0.992	0.984	0.015
	12-14	1.420	-0.674	0.997	0.994	0.010
	18-20	0.924	-0.005	0.995	0.990	0.010
Average				0.991	0.982	0.009

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(17) Tonggo Ri						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02					
	06-08	0.707	-0.046	0.991	0.982	0.011
	12-14	0.886	-0.279	0.997	0.994	0.007
	18-20					
April	00-02					
	06-08	0.907	-0.732	0.992	0.984	0.009
	12-14	1.101	-0.925	0.996	0.992	0.010
	18-20					
July	00-02					
	06-08	1.154	-1.709	0.995	0.990	0.009
	12-14	2.087	-2.204	0.992	0.984	0.011
	18-20					
October	00-02					
	06-08	1.029	-0.351	0.996	0.992	0.010
	12-14	1.345	-0.615	0.996	0.992	0.013
	18-20					
Average				0.994	0.988	0.010

Table 4. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each Korean Station and Time Period in the Model Study (Contd)

4(18) Tongduchon						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02					
	06-08	0.553	-0.006	0.992	0.984	0.008
	12-14	0.837	-0.280	0.994	0.988	0.010
	18-20					
April	00-02					
	06-08	0.862	-0.751	0.994	0.988	0.010
	12-14	1.178	-1.001	0.993	0.986	0.013
	18-20					
July	00-02					
	06-08	1.263	-1.730	0.985	0.970	0.013
	12-14	2.147	-2.238	0.997	0.994	0.011
	18-20					
October	00-02					
	06-08	1.083	-0.498	0.993	0.986	0.014
	12-14	1.390	-0.703	0.994	0.988	0.016
	18-20					
Average				0.993	0.986	0.012

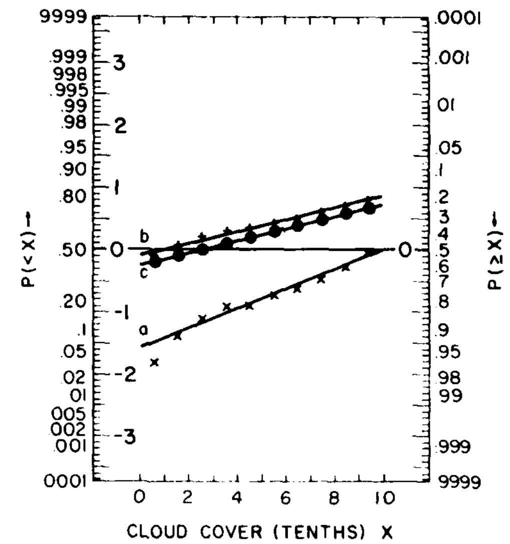

Figure 5. Simplified Linear Model Cumulative Probability Estimates of Fractional Cloud Cover for (a) "Worst" Model Case (Chinhae, Jul, 12-14 LST), (b) "Average" Model Case (Kangnung, Jan, 18-20 LST), and (c) "Best" Model Case (Chunchon, Jan, 18-20 LST) over Korea Compared With Data. Solid lines represent the SLM Model probability; the data values for a, b, and c are marked by x's, crosses, and dots, respectively. Note the excellent model fit for the "best" case, with data and model values being indistinguishable on the graph

3.3.2 MODEL B IN KOREA

In Figures 8a-8p the mean sky cover for all 26 Korean stations in Table 2 is subjectively analyzed for all specified times and months. These stations are located geographically in Figure 4b. Likewise, Figures 9a-9p show the analyses of the scale distances that were calculated from the 18 stations used in the SLM study.

Figures 8 and 9 provide pairs of values of the two parameters (P_o, r) that are needed for Model B. For the cloudiest period at the cloudiest station (Mosulp-O, in January, for 12-14 LST) the values $P_o = 0.78$, $r = 1.6$ km, which were read from Figures 8 and 9, yielded values for the cumulative probability distribution of the cloud cover as shown by curve a of Figure 10. The data are represented by the X's. For the same station when there is minimum cloudiness, (October, for 18-20 LST), the parameters were likewise read from Figures 8 and 9 ($P_o = 0.49$,

Table 5. Observed Values and Simplified Linear Model Values for the Cumulative Frequency of Sky Cover, and the Differences in These Values, for the Worst (a), Average (b), and Best (c) Simplified Linear Model Cases in Korea

Sky Cover Proportion	Observed Frequency (Cumulative)	Model Frequency (Cumulative)	Difference
(a) Chinhae - July, 12-14 LST - "Worst" Case			
0.05	0.035	0.056	-0.021
0.15	0.083	0.078	0.005
0.25	0.136	0.105	0.031
0.35	0.167	0.140	0.027
0.45	0.198	0.181	0.017
0.55	0.236	0.229	0.007
0.65	0.255	0.283	-0.028
0.75	0.307	0.343	-0.036
0.85	0.399	0.408	-0.009
0.95	0.489	0.475	0.014
(b) Kangnung - January, 18-20 LST - "Average" Case			
0.05	0.454	0.479	-0.025
0.15	0.514	0.517	-0.003
0.25	0.566	0.556	0.010
0.35	0.616	0.595	0.021
0.45	0.646	0.632	0.014
0.55	0.672	0.669	0.003
0.65	0.700	0.704	-0.004
0.75	0.733	0.736	-0.003
0.85	0.774	0.767	0.007
0.95	0.791	0.796	-0.005
(c) Chunchon - January, 18-20 LST - "Best" Case			
0.05	0.415	0.423	-0.008
0.15	0.461	0.462	-0.001
0.25	0.505	0.500	0.005
0.35	0.543	0.539	0.004
0.45	0.585	0.577	0.008
0.55	0.614	0.615	-0.001
0.65	0.649	0.652	-0.003
0.75	0.689	0.687	0.002
0.85	0.718	0.721	-0.003
0.95	0.756	0.752	0.004

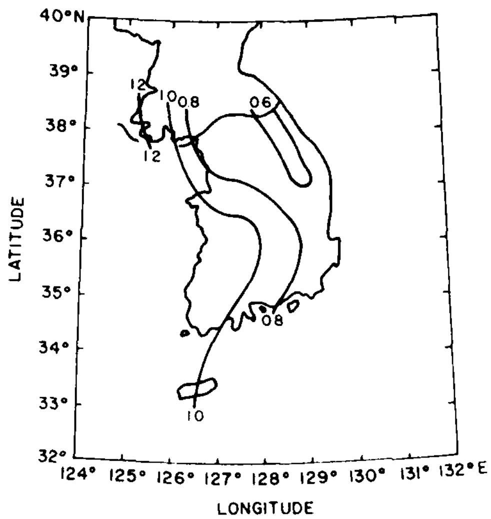

Figure 6a. January 00-02 LST

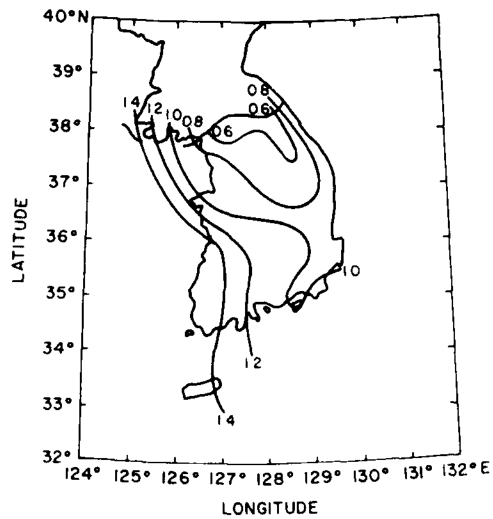

Figure 6b. January 06-08 LST

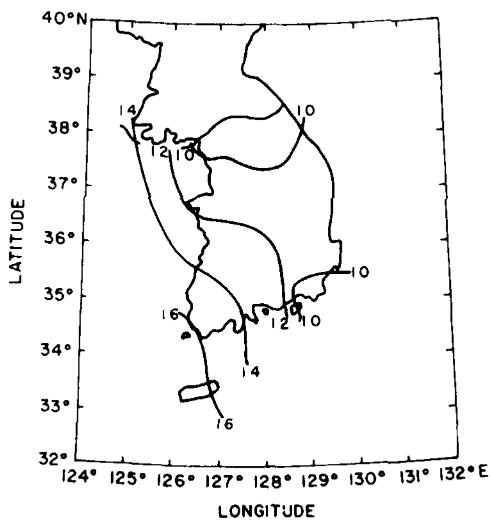

Figure 6c. January 12-14 LST

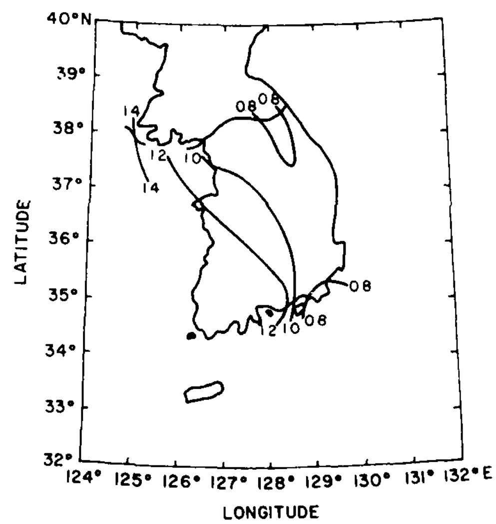

Figure 6d. January 18-20 LST

Figure 6. SLM Parameter a, Over Korea. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

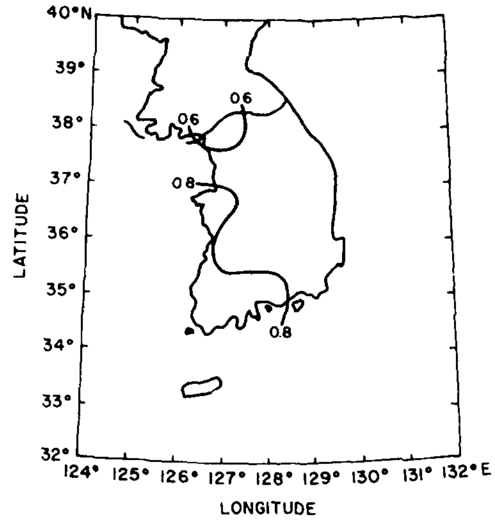

Figure 6e. April 00-02 LST

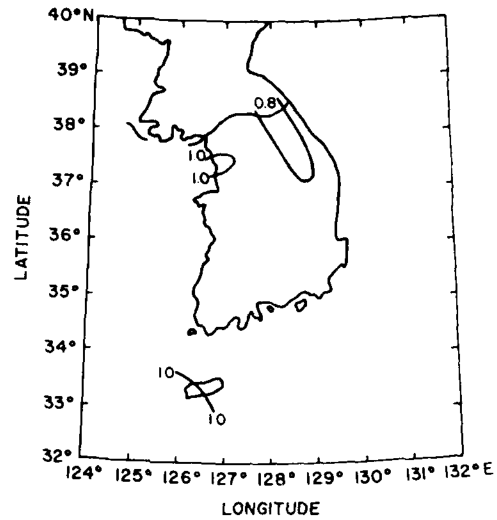

Figure 6f. April 06-08 LST

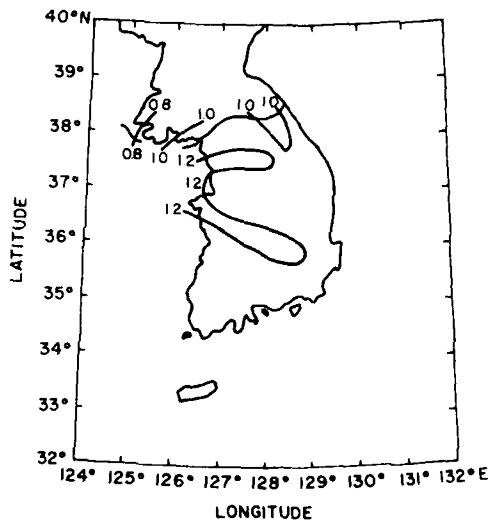

Figure 6g. April 12-14 LST

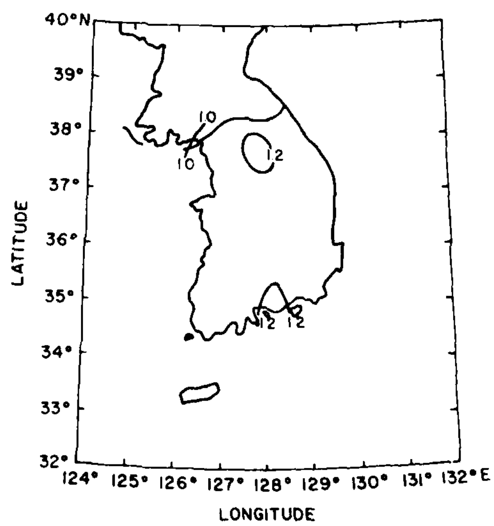

Figure 6h. April 18-20 LST

Figure 6. SLM Parameter a, Over Korea. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

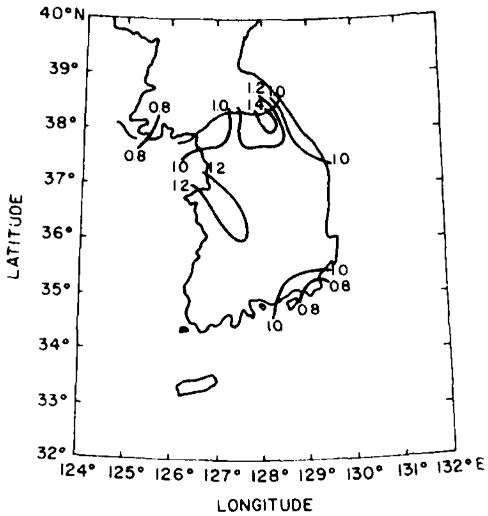

Figure 6i. July 00-02 LST

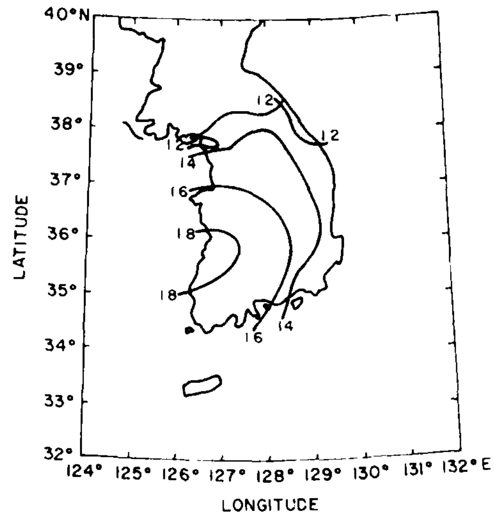

Figure 6j. July 06-08 LST

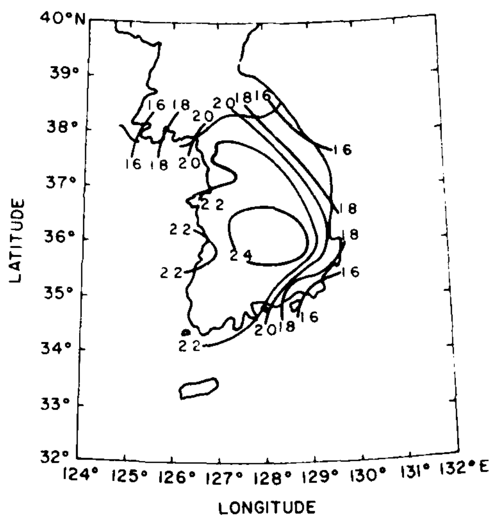

Figure 6k. July 12-14 LST

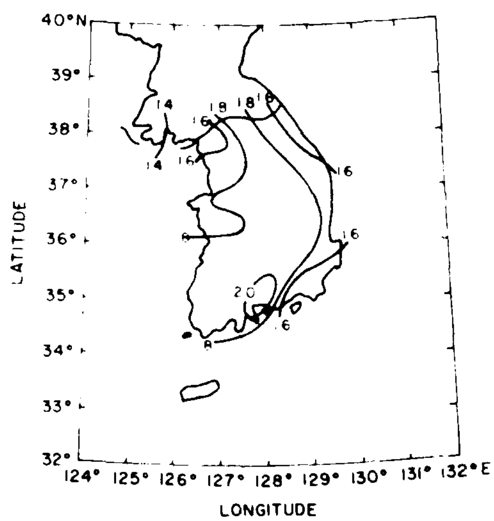

Figure 6l. July 18-20 LST

Figure 6. SLM Parameter a, Over Korea. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

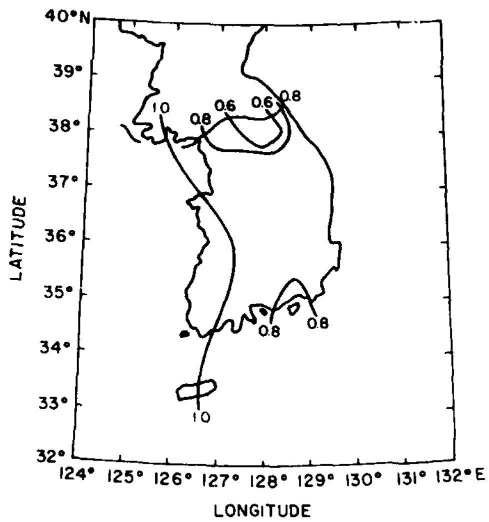

Figure 6m. October 00-02 LST

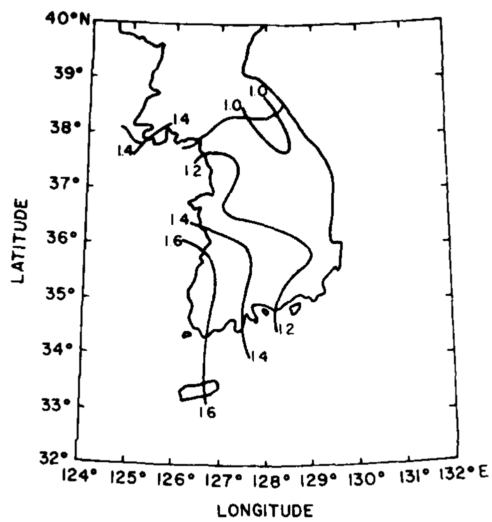

Figure 6n. October 06-08 LST

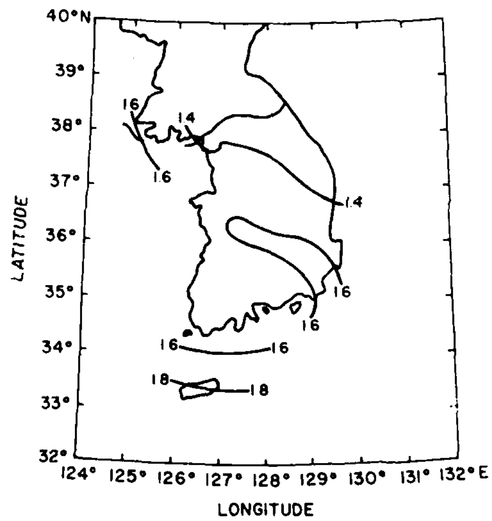

Figure 6o. October 12-14 LST

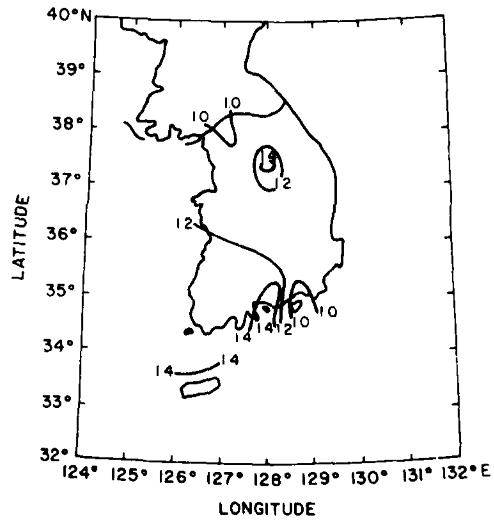

Figure 6p. October 18-20 LST

Figure 6. SLM Parameter a, Over Korea. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

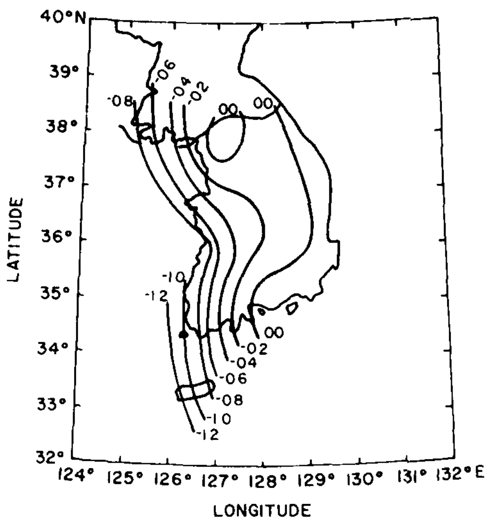

Figure 7a. January 00-02 LST. In this case, the frequency of clear sky increases from 15 percent on the west coast to 50 percent inland and near the east coast

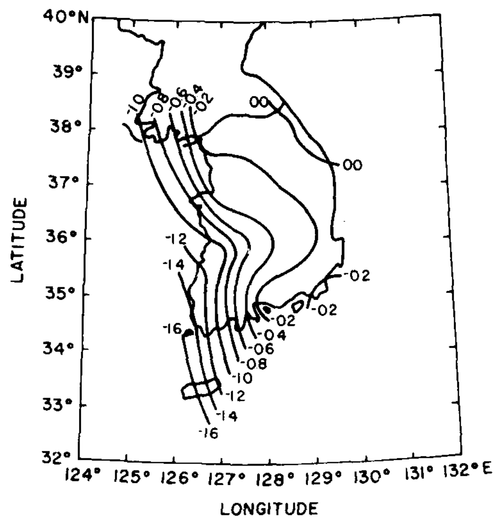

Figure 7b. January 06-08 LST

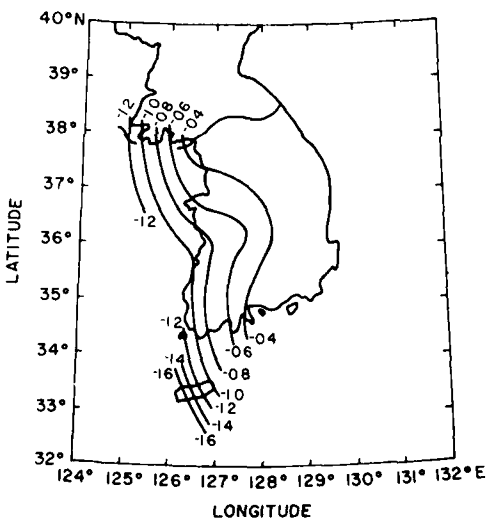

Figure 7c. January 12-14 LST

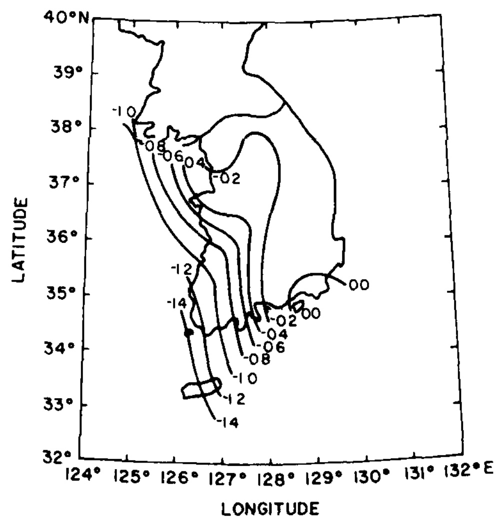

Figure 7d. January 18-20 LST

Figure 7. SLM Parameter b, Over Korea. This parameter is the END of the probability of clear

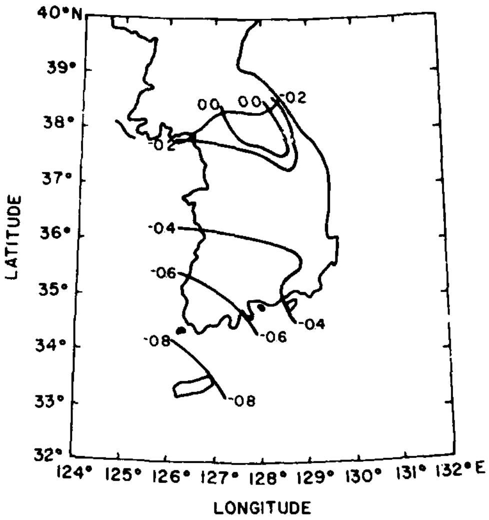

Figure 7e. April 00-02 LST

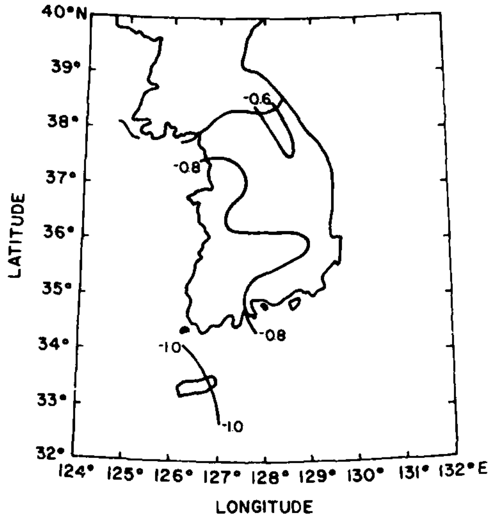

Figure 7f. April 06-08 LST

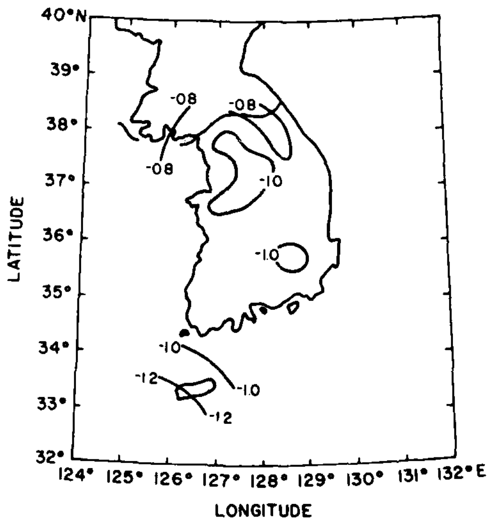

Figure 7g. April 12-14 LST

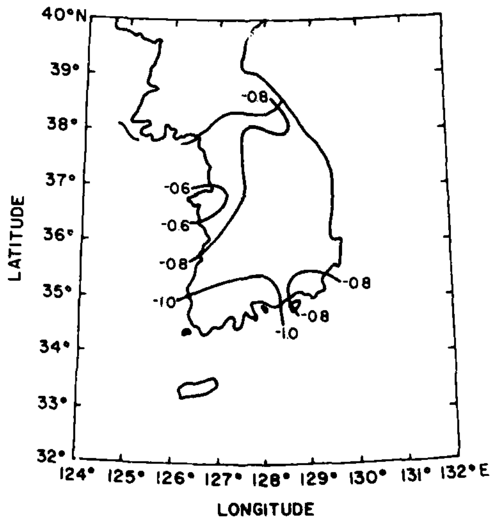

Figure 7h. April 18-20 LST

Figure 7. SLM Parameter b, Over Korea. This parameter is the END of the probability of clear

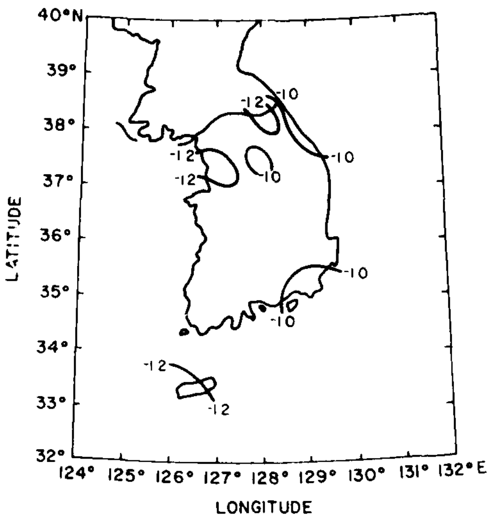

Figure 7i. July 00-02 LST

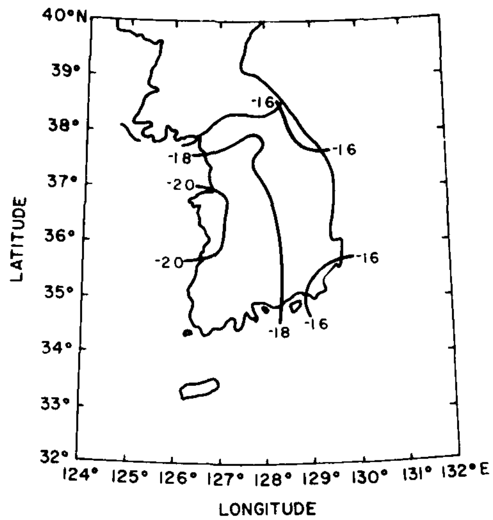

Figure 7j. July 06-08 LST

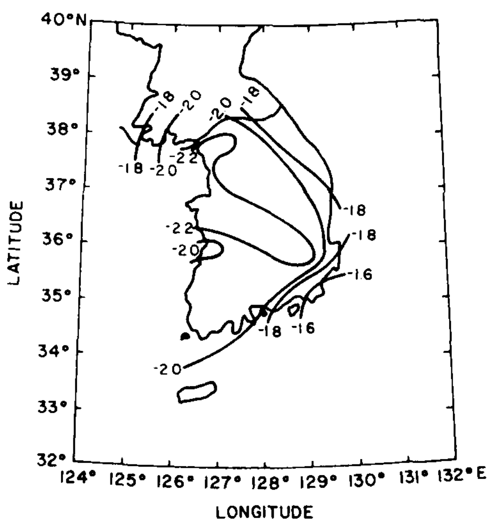

Figure 7k. July 12-14 LST

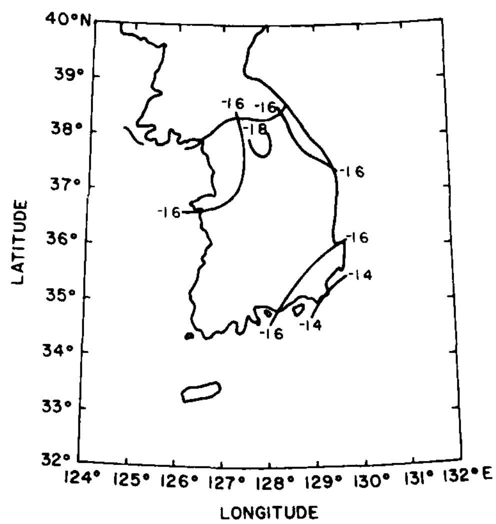

Figure 7l. July 18-20 LST

Figure 7. SLM Parameter b, Over Korea. This parameter is the END of the probability of clear

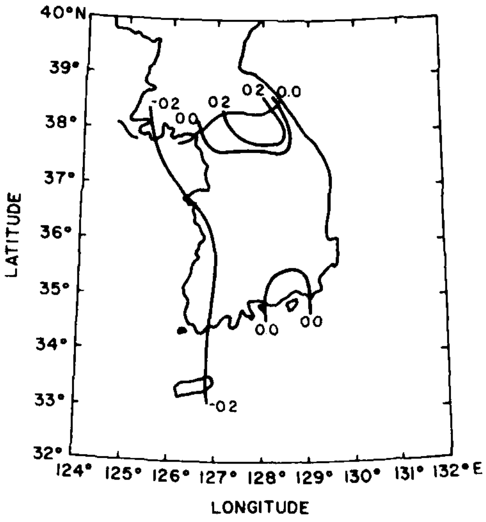

Figure 7m. October 00-02 LST

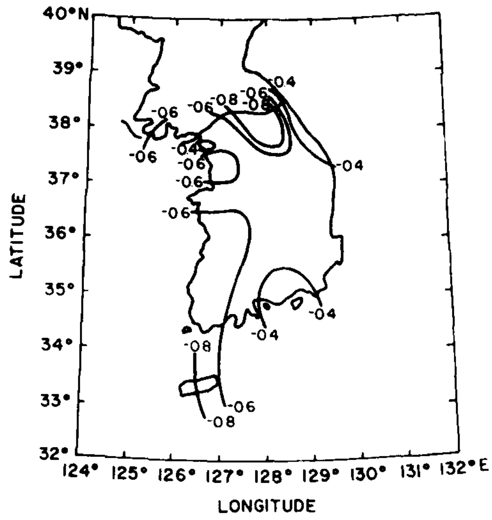

Figure 7n. October 06-08 LST

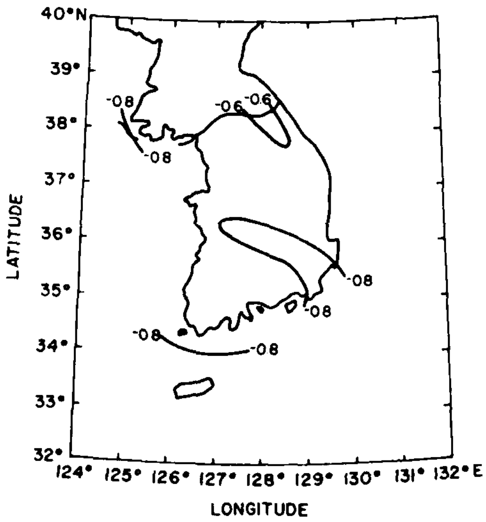

Figure 7o. October 12-14 LST

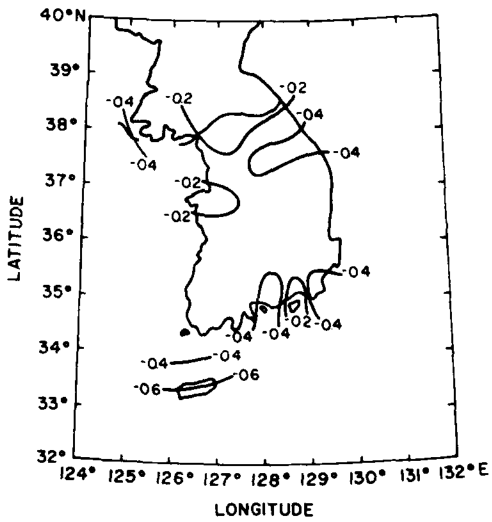

Figure 7p. October 18-20 LST

Figure 7. SLM Parameter b, Over Korea. This parameter is the END of the probability of clear

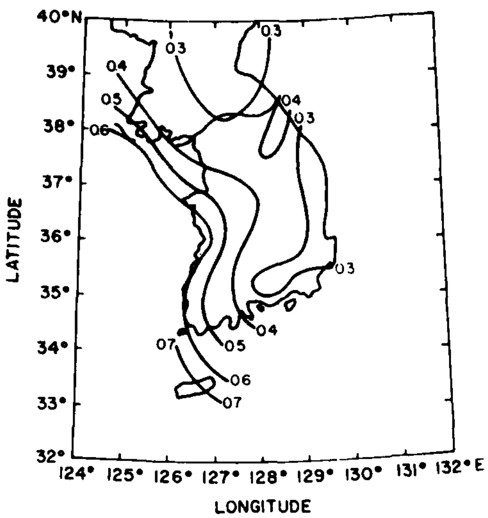

Figure 8a. Mean Sky Cover P_o for January, 00-02 LST, Over Korea

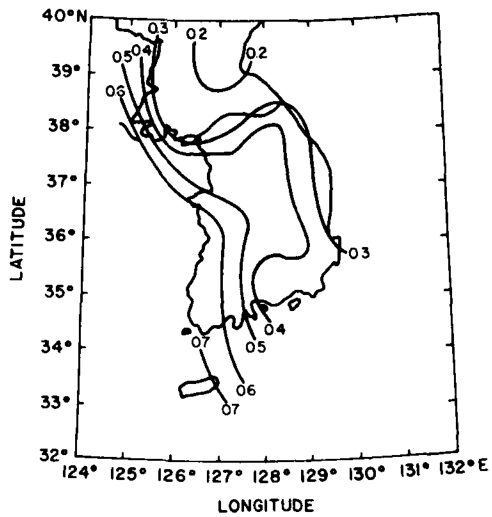

Figure 8b. Mean Sky Cover P_o for January, 06-08 LST, Over Korea

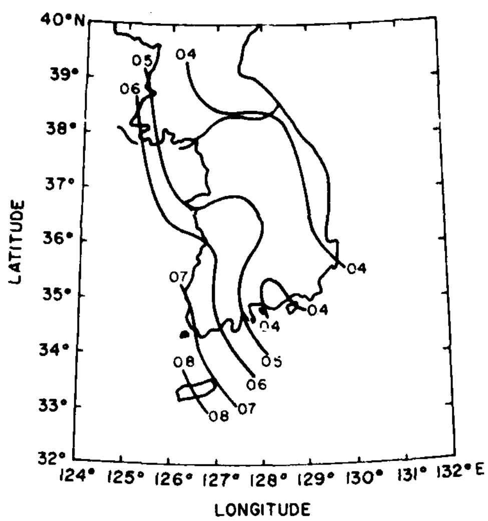

Figure 8c. Mean Sky Cover P_o for January, 12-14 LST, Over Korea

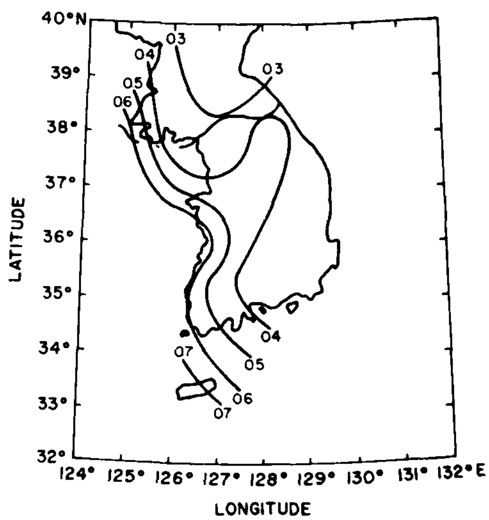

Figure 8d. Mean Sky Cover P_o for January, 18-20 LST, Over Korea

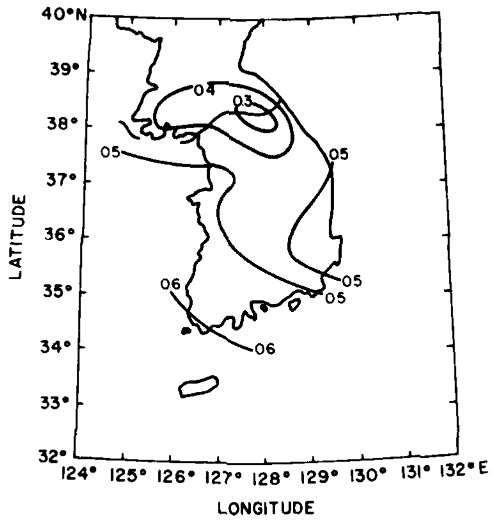

Figure 8e. Mean Sky Cover P_o for April, 00-02 LST, Over Korea

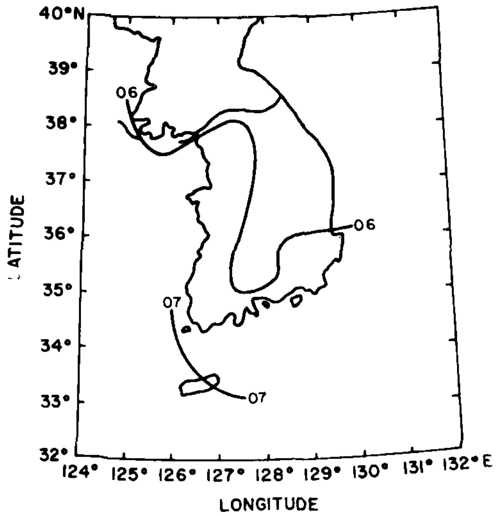

Figure 8f. Mean Sky Cover P_o for April, 06-08 LST, Over Korea

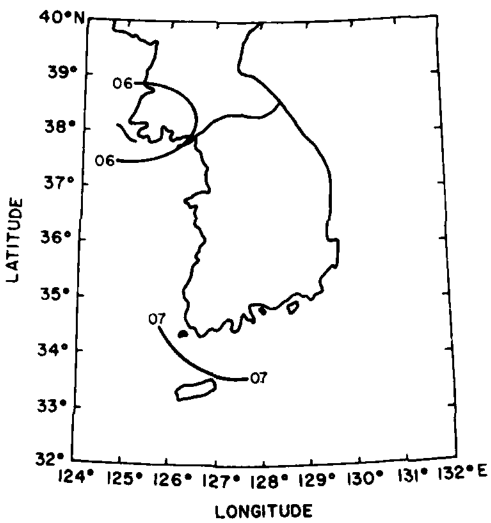

Figure 8g. Mean Sky Cover P_o for April, 12-14 LST, Over Korea

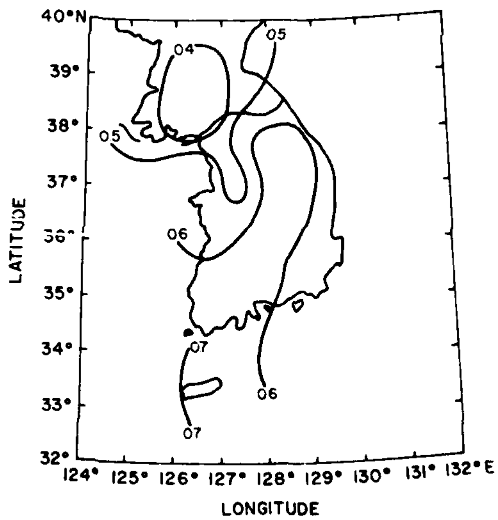

Figure 8h. Mean Sky Cover P_o for April, 18-20 LST, Over Korea

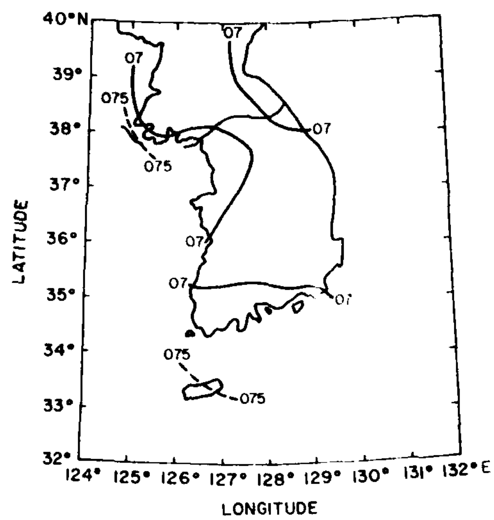

Figure 8i. Mean Sky Cover P_o for July, 00-02 LST, Over Korea

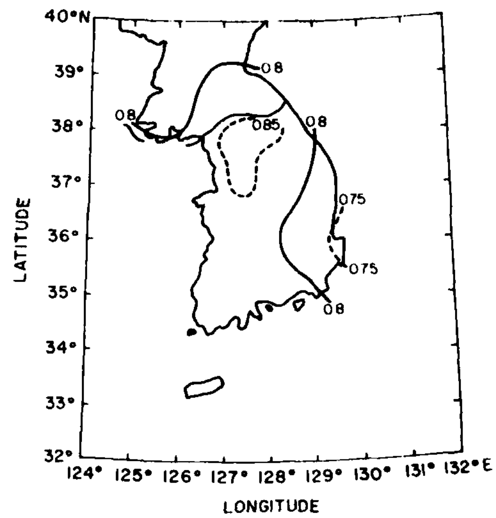

Figure 8j. Mean Sky Cover P_o for July, 06-08 LST, Over Korea

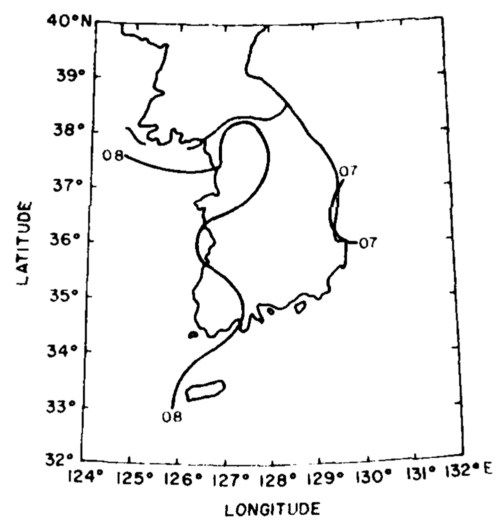

Figure 8k. Mean Sky Cover P_o for July, 12-14 LST, Over Korea

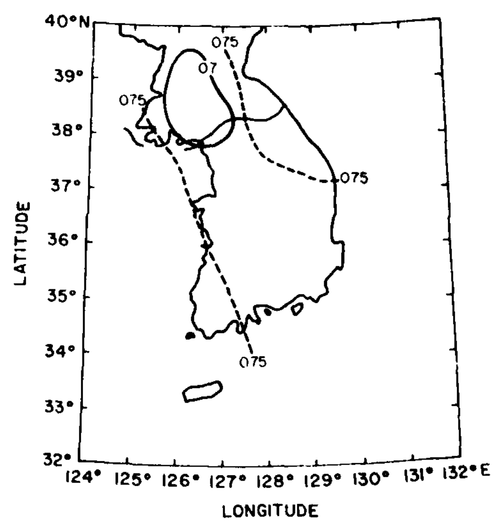

Figure 8l. Mean Sky Cover P_o for July, 18-20 LST, Over Korea

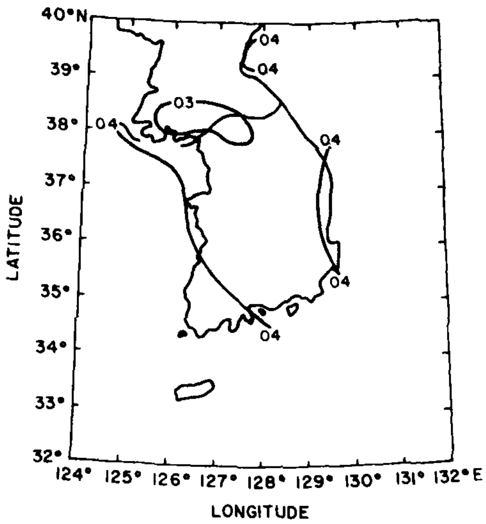

Figure 8m. Mean Sky Cover P_o for October, 00-02 LST, Over Korea

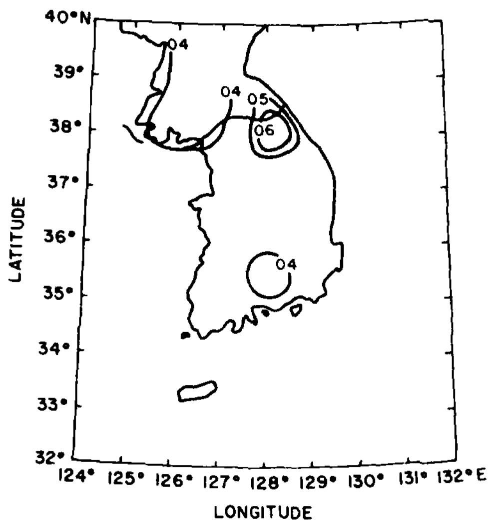

Figure 8n. Mean Sky Cover P_o for October, 06-08 LST, Over Korea

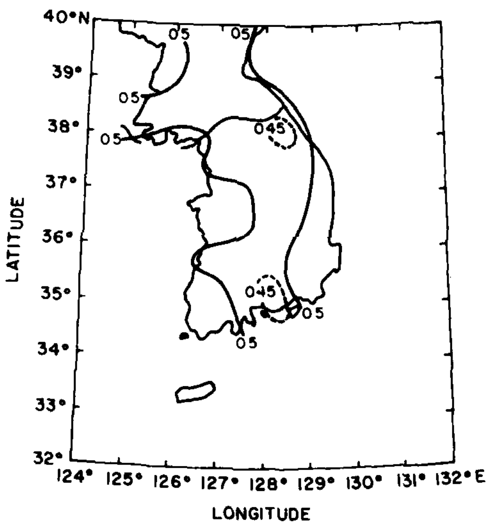

Figure 8o. Mean Sky Cover P_o for October, 12-14 LST, Over Korea

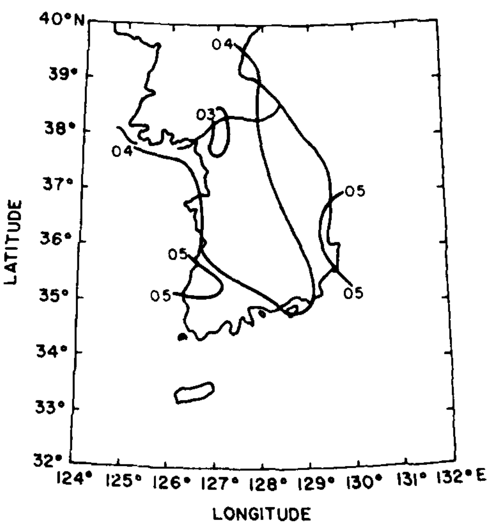

Figure 8p. Mean Sky Cover P_o for October, 18-20 LST, Over Korea

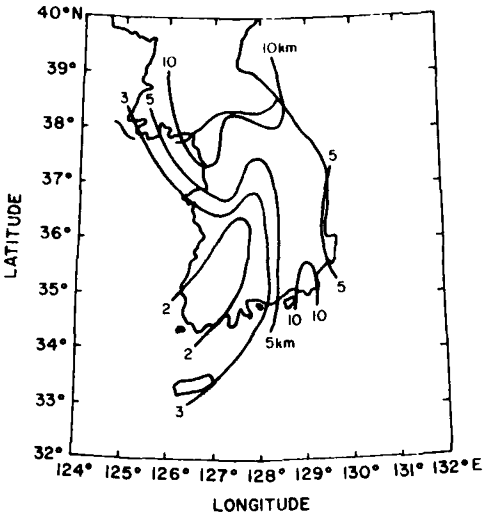

Figure 9a. Scale Distance r for January, 00-02 LST, Over Korea

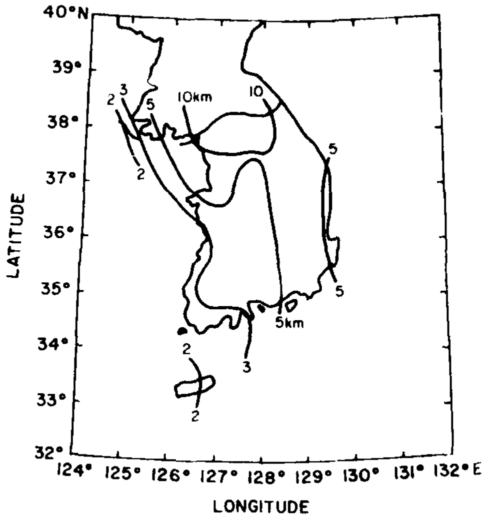

Figure 9b. Scale Distance r for January, 06-08 LST, Over Korea

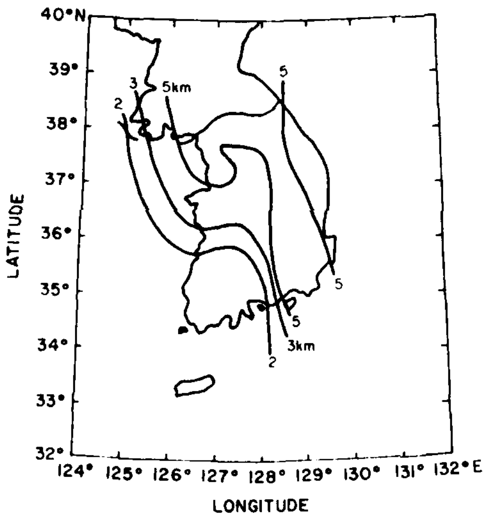

Figure 9c. Scale Distance r for January, 12-14 LST, Over Korea

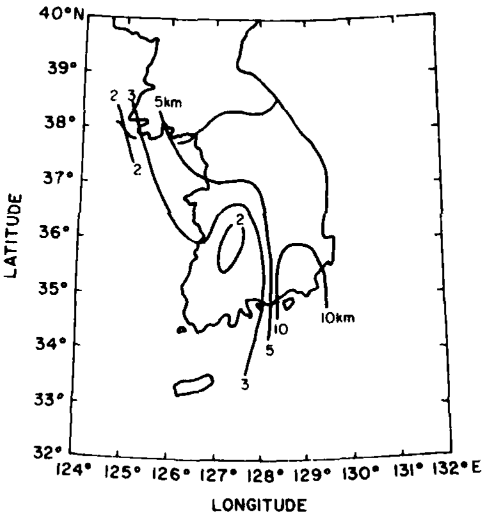

Figure 9d. Scale Distance r for January, 18-20 LST, Over Korea

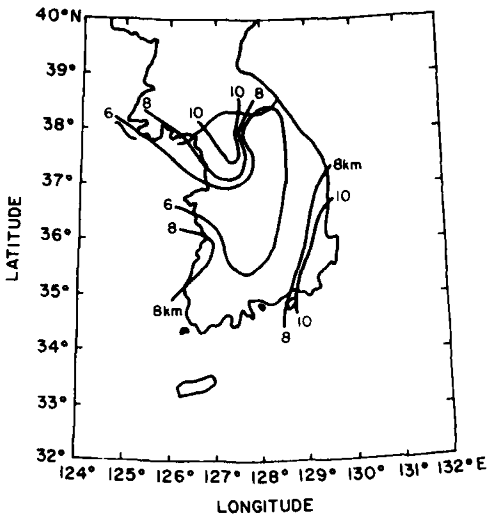

Figure 9e. Scale Distance r for April, 00-02 LST, Over Korea

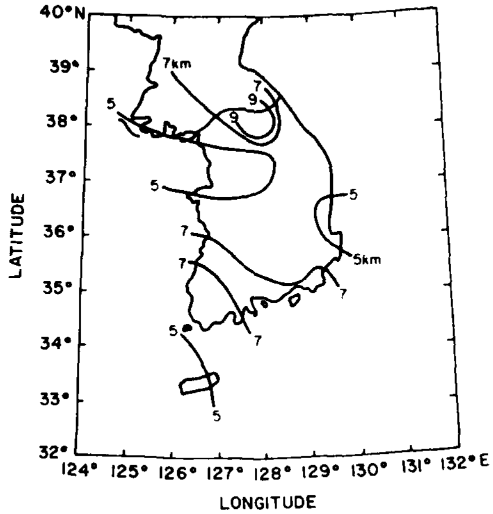

Figure 9f. Scale Distance r for April, 06-08 LST, Over Korea

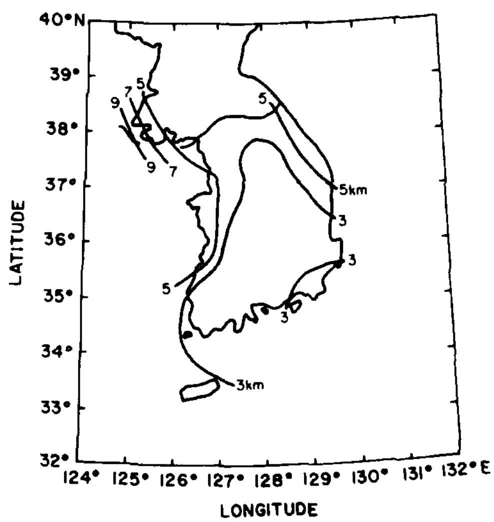

Figure 9g. Scale Distance r for April, 12-14 LST, Over Korea

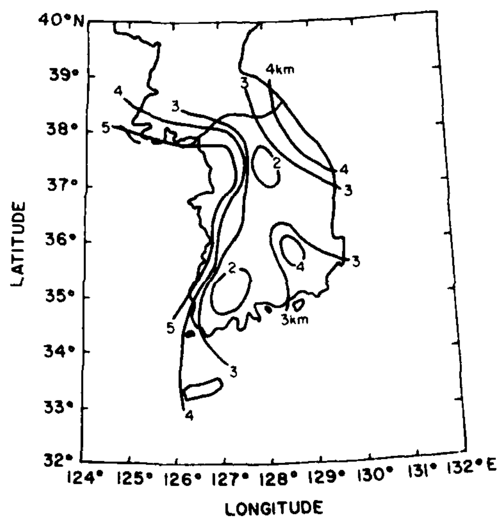

Figure 9h. Scale Distance r for April, 18-20 LST, Over Korea

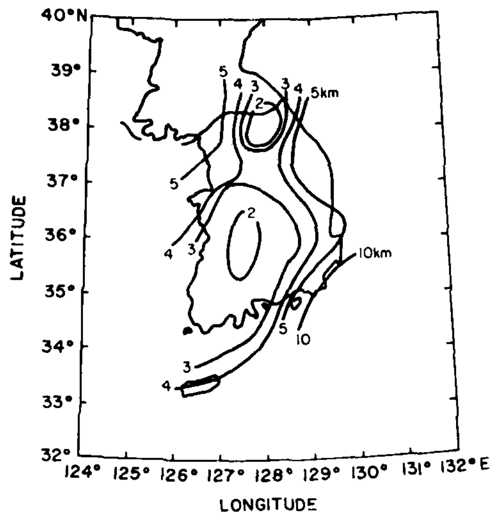

Figure 9i. Scale Distance r for July, 00-02 LST, Over Korea

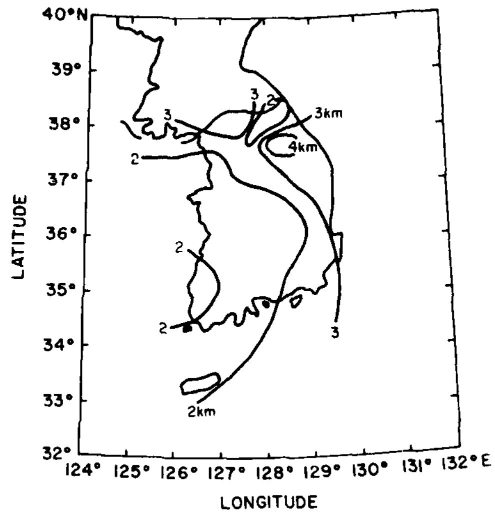

Figure 9j. Scale Distance r for July, 06-08 LST, Over Korea

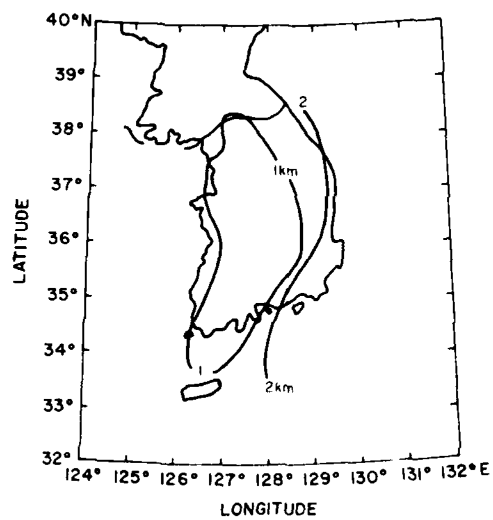

Figure 9k. Scale Distance r for July, 12-14 LST, Over Korea

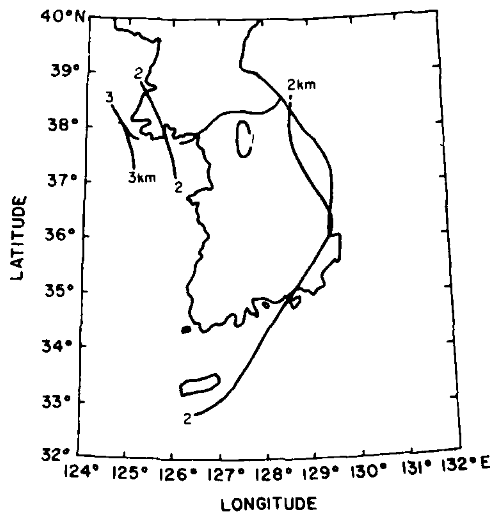

Figure 9l. Scale Distance r for July, 18-20 LST, Over Korea

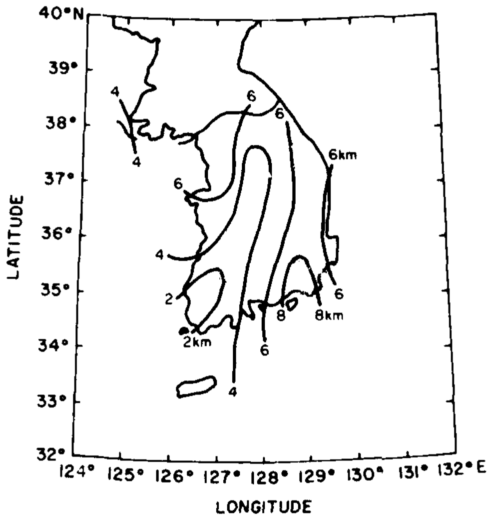

Figure 9m. Scale Distance r for October, 00-02 LST, Over Korea

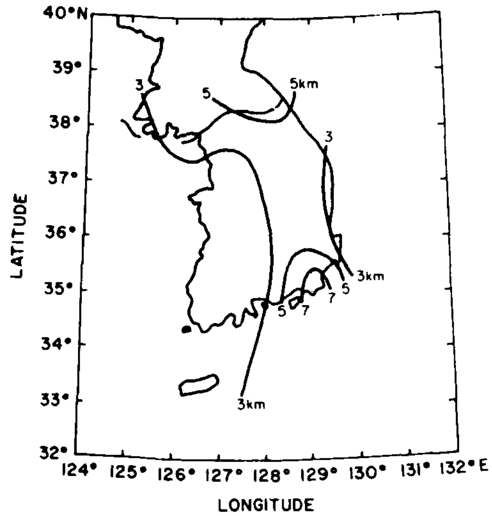

Figure 9n. Scale Distance r for October, 06-08 LST, Over Korea

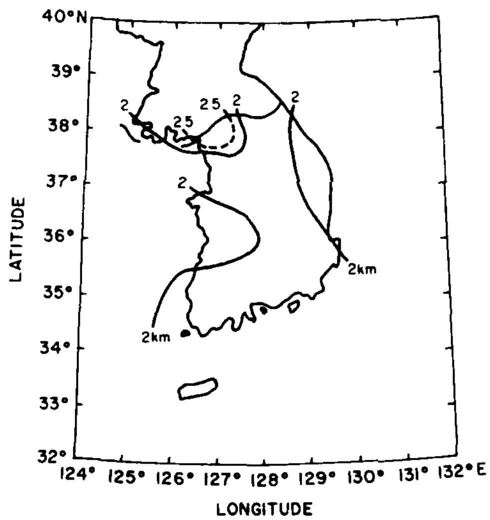

Figure 9o. Scale Distance r for October, 12-14 LST, Over Korea

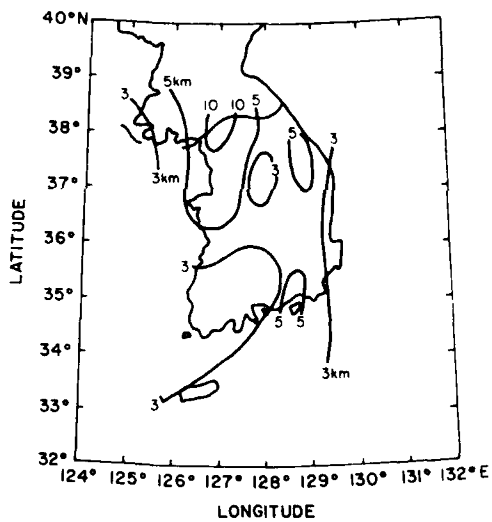

Figure 9p. Scale Distance r for October, 18-20 LST, Over Korea

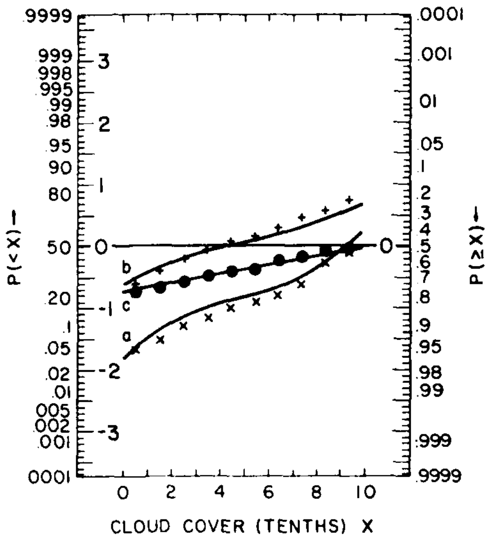

Figure 10. Model B Cumulative Probability Estimates of Fractional Cloud Cover for the Cloudiest Korean Station (Mosulp-O) for (a) The Cloudiest Period (January, 12-14 LST), (b) The Period of Minimum Cloudiness (October, 18-20 LST), and (c) The Period With the Largest Scale Distance (April, 00-02 LST) Compared With Data. Solid lines are model calculations and the data values for a, b, and c are marked by x's, crosses, and dots, respectively

r = 3.2 km) and used in Model B. This curve is shown as b in Figure 10, along with the data points (crosses). Finally, the parameters were also read for April, for 00-02 LST, when the scale distance was large (P_o = 0.65, r = 7.0 km), and used in Model B (curve c in Figure 10). The average rms error for the three examples is 0.022.

For the least cloudy station, Pusan East, similar estimates were made (Figure 11), with an average rms error of 0.017.

To illustrate the model use for areal coverages smaller and larger than the observer's field of view, a point was selected at 36°N, 128°E, in the cloudiest period, July, for 06-08 LST. Figures 8 and 9 give P_o = 8.0, r = 1.1 km. As shown in Figure 12, Model B provides the probability distributions for areal coverages of 24, 2424 (sky cover), and 24,240 km^2. Whereas an observer has a 35 percent probability of seeing an overcast sky, a satellite view of 10 times the size of the observer's sky dome has only a 2 percent probability of showing full overcast.

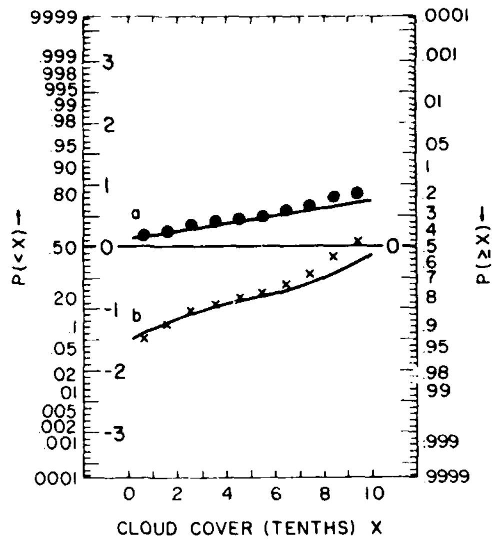

Figure 11. Model B Cumulative Probability Estimates of Fractional Cloud Cover for the Least Cloudy Korean Station (Pusan East) for (a) The Period January, 00-02 LST, and (b) The Period July, 06-08 LST Compared With Data. Solid lines are model calculations and the data values for a and b are marked by dots and x's respectively.

3.3.3 ANALYSIS OF KOREAN RESULTS

If relationships could be found between the model parameters and mesoscale geographic features, then it would be possible to describe the climatology of total cloud cover at any point in the area, provided the models hold throughout the region and provided the appropriate geographic information is known. A complete mesoscale climatological model of total cloud cover will have been developed. Unfortunately, the data coverage, as shown in Figure 4, is too sparse to allow for the discovery of such detailed relationships. The central and southwestern portion of South Korea is a region of mountainous terrain, with elevations as high as 1,200 to 1,500 m. But mountain region stations are absent from the data set (Figure 4). Most of the elevations of the stations for which we have data are below 30 m, and the highest is only 198 m (Table 2). One would expect the mountainous regions to have a significant effect on the cloudiness, and thus an important element in the mesoscale study is lacking.

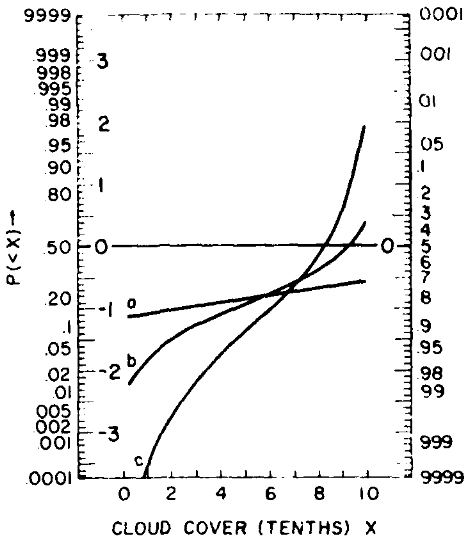

Figure 12. Model B Cumulative Probability Estimates of Fractional Cloud Cover at a Point 36°N, 128°E During July, 06-08 LST, for Areal Coverages of (a) 1 Percent of the Observer's Field of View (24 km^2), (b) The Observer's Field of View (2424 km^2) and (c) Ten Times the Observer's Field of View (24,240 km^2)

Despite the lack of data, examination of Figures 6, 7, 8, and 9 reveals that geographic relationships may exist. For example, the January analyses show that SLM parameter a tends to increase and parameter b tends to decrease toward the west and south [Figures 6a-6d and Figures 7a-7d]. Figure 6k indicates that parameter a reaches a maximum in central South Korea in July for 12-14 LST. P_o also tends to increase toward the southwest during January [Figures 8a-8d], and r decreases in that direction [Figure 9a-9d]. These geographic patterns probably reflect the effects of the general circulation. The vigorous circulation of winter lends itself to strong gradients. In Korea, winter winds are generally northwesterly, bringing cold Siberian air from Asia. As the cold air passes over the Yellow Sea to the west it picks up moisture. In its eastward passage across the Korean peninsula, it begins to dry out. Thus, the higher values of P_o are on the western side of the peninsula. Similarly, lower values of parameter b are found in this region. In July, when the circulation is less vigorous, gradients in model parameters b and P_o are more relaxed [Figures 7i-7l, and 8i-8l]. There is also a general increase in cloudiness throughout the entire region due to the southerly, moisture-laden winds. The higher values of r in the winter as opposed

to summer show that the sky cover is more persistent during the colder months. The implication is that winter storm clouds are normally of the stratiform variety and summer clouds are generally cumuliform. This is revealed in Figure 13, where the average scale distances of all stations are analyzed as a function of time of day and time of year. The lower values of r around midday reflect the tendency toward increased cumuliform cloudiness at that time.

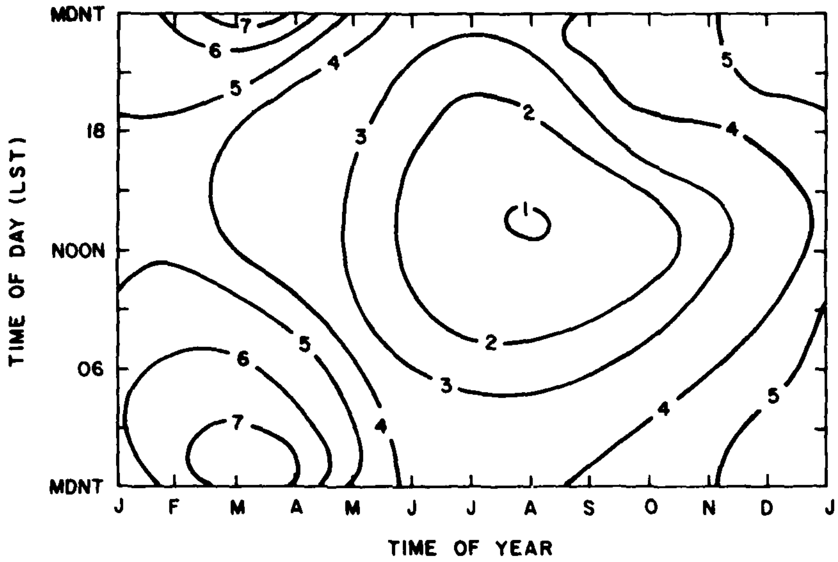

Figure 13. Analysis Over All Time Periods of the Average Values of the Scale Distance r for the Korean Stations

All told, the characteristics of the cloud cover over Korea indicate the need for attention to mesoscale details with respect to season, time of day, and geographic location. The SLM fits the data very well, as does Model B. Because of its simplicity in comparison with Model B, the SLM is preferred in most cases. However, for cases where the sky cover distribution is needed for areal coverages different from that of the observer's field of view, Model B is the appropriate method.

3.4 Model Study in Germany

In this section of the report the results of the SLM and Model B tests on the German data are presented and analyzed.

3.4.1 THE SLM IN GERMANY

SLM parameters a and b were calculated for the German stations numbered 1-19 and 51-64 in Table 3 for all specified times and months except for Bad Kreuznach, Sandhofen, and Illesheim, which had data missing during the 00-02 LST time period. These stations are located geographically in Figure 14a. The parameter values, along with ρ, ρ^2, and rms errors, are shown in Tables 6(1)-6(33). The explained variation of Z ranges from 0.834 to 0.998. Therefore, the variation left unexplained by the regression equation ranges from 0.2 to 16.6 percent. Station averages for ρ^2 range from 0.917 to 0.988, and the overall mean is 0.963. Only 3.3 percent of the values fell below 0.900. The rms errors range from 0.004 to 0.076, with station averages ranging from 0.015 to 0.049, and an overall mean of 0.027. Only 9 percent of the rms error values were greater than 0.049. Examples of a "worst-fit" case, an "average-fit" case, and a "best-fit" case are shown graphically in Figure 15. The worst case is Hannover in January for 12-14 LST with a ρ^2 of 0.834 and an rms error of 0.075. The average case is Dresden in October for 18-20 LST with a ρ^2 of 0.962 and an rms error of 0.027. The best case is Heidelberg in January for 00-02 LST, with a ρ^2 of 0.998 and an rms error of 0.004. The lines in the figure are the model fits and the data are marked by the X's, dots and crosses, respectively, for the worst, average and best cases. As in Korea, the difference between the model and data values for the best case cannot be distinguished on the graph. These three cases are shown in Tables 7a-7c. The differences in observed and model cumulative frequencies ranges from 0.1 to 17.1 percent (absolute value). Note that only one value was greater than 10 percent. The model frequency lies above and below the observed frequency about equally.

Figures 16a-16p show the subjective analyses of model parameter a and Figures 17a-17p show the subjective analyses of parameter b for all time periods.

3.4.2 MODEL B IN GERMANY

In Figures 18a-18p, P_o for the first 52 stations of Table 3 is subjectively analyzed. The locations of these stations are shown on the map of Figure 14b. Scale distances were obtained using the first 28 stations of Table 3. Their locations are shown in Figure 14c. The scale distances displayed little or no systematic differences with geography. No pattern emerged among the values when plotted on maps of Germany. Average values of r for all stations are analyzed as a function of time of day and year in Figure 19. A distinct pattern is revealed, with significant differences from season to season and noon to midnight.

Cumulative probabilities of sky cover ($x = 0$, $\leq 1/4$, $\leq 1/2$, $\leq 3/4$, ≤ 1) were determined for the first eight stations of Table 3 for all months and times of day.

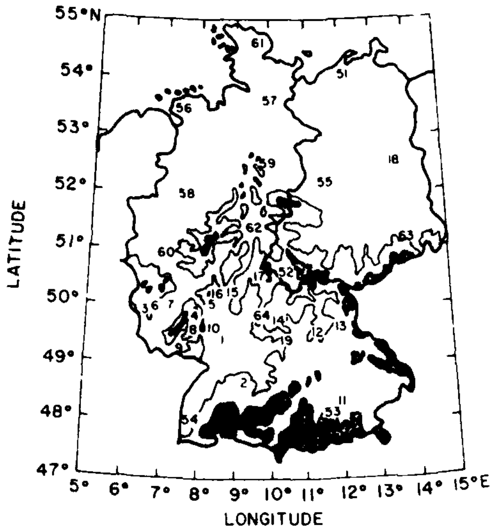

Figure 14a. Locations of the German Stations Used in the Simplified Linear Model Study. Station identifiers correspond to the numbers of Table 3

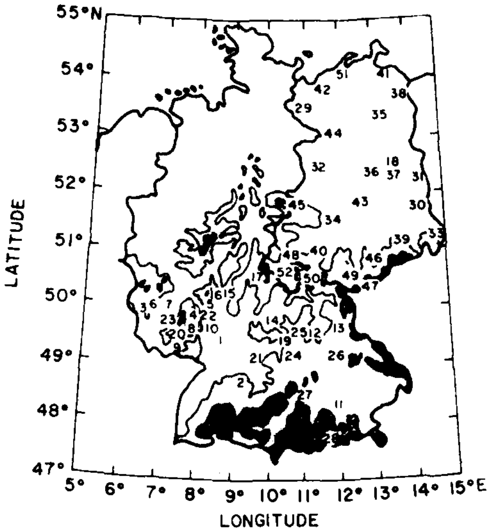

Figure 14b. Locations of the German Stations Used in the Mean Sky Cover (P_o) Analysis

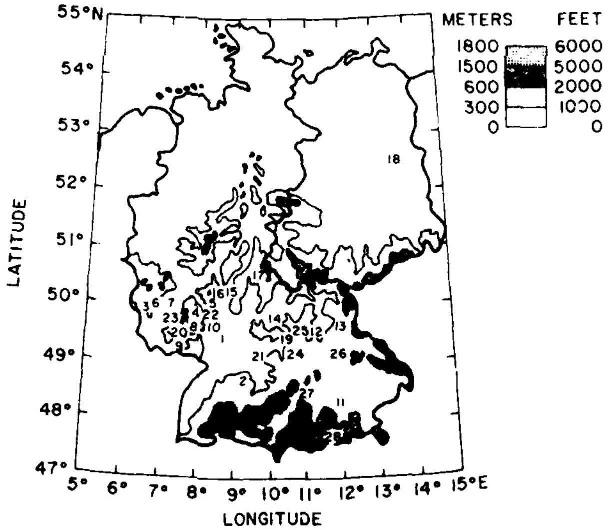

Figure 14c. Locations of the German Stations *Used in the Scale Distance (r) Analysis*

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study

6(1) Heidelberg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.839	-1.032	0.999	0.998	0.004
	06-08	1.136	-1.446	0.995	0.990	0.010
	12-14	1.279	-1.637	0.984	0.968	0.020
	18-20	1.034	-1.263	0.998	0.996	0.004
April	00-02	0.995	-0.669	0.998	0.996	0.007
	06-08	1.410	-1.276	0.993	0.986	0.018
	12-14	1.945	-1.786	0.991	0.982	0.024
	18-20	1.706	-1.339	0.992	0.984	0.017
July	00-02	1.260	-0.744	0.999	0.998	0.005
	06-08	1.465	-1.199	0.991	0.982	0.021
	12-14	2.330	-1.913	0.990	0.980	0.032
	18-20	1.838	-1.375	0.992	0.984	0.024
October	00-02	0.987	-0.690	0.998	0.996	0.007
	06-08	1.311	-1.387	0.984	0.968	0.023
	12-14	1.479	-1.349	0.984	0.968	0.028
	18-20	1.280	-0.949	0.996	0.992	0.012
Average				0.993	0.986	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(2) Stuttgart						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.820	-1.034	0.984	0.968	0.016
	06-08	1.123	-1.402	0.972	0.945	0.028
	12-14	1.286	-1.425	0.954	0.910	0.041
	18-20	0.936	-1.148	0.984	0.968	0.017
April	00-02	1.132	-0.844	0.990	0.980	0.018
	06-08	1.414	-1.257	0.978	0.956	0.032
	12-14	1.951	-1.749	0.976	0.953	0.043
	18-20	1.612	-1.338	0.986	0.972	0.029
July	00-02	1.266	-0.673	0.988	0.976	0.021
	06-08	1.515	-0.985	0.964	0.929	0.042
	12-14	2.402	-1.732	0.984	0.968	0.039
	18-20	1.516	-1.108	0.982	0.964	0.061
October	00-02	0.776	-0.506	0.991	0.982	0.012
	06-08	1.185	-1.058	0.975	0.951	0.029
	12-14	1.564	-1.167	0.980	0.960	0.033
	18-20	1.074	-0.675	0.985	0.970	0.021
Average				0.980	0.960	0.030

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(3) Bitburg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.776	-1.127	0.996	0.992	0.006
	06-08	0.955	-1.401	0.993	0.986	0.009
	12-14	1.152	-1.526	0.994	0.988	0.008
	18-20	0.939	-1.174	0.994	0.988	0.008
April	00-02	1.013	-0.555	0.999	0.998	0.005
	06-08	1.317	-1.290	0.988	0.976	0.020
	12-14	1.941	-1.830	0.985	0.970	0.033
	18-20	1.745	-1.415	0.993	0.986	0.015
July	00-02	1.123	-0.604	0.992	0.984	0.015
	06-08	1.426	-1.338	0.990	0.980	0.021
	12-14	2.207	-2.049	0.986	0.972	0.035
	18-20	1.913	-1.536	0.995	0.990	0.018
October	00-02	0.842	-0.757	0.997	0.994	0.006
	06-08	1.126	-1.420	0.981	0.962	0.019
	12-14	1.370	-1.389	0.985	0.970	0.025
	18-20	1.186	-0.912	0.993	0.986	0.014
Average				0.991	0.983	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(4) Bad Kreuznach						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02					
	06-08	0.995	-1.414	0.997	0.994	0.010
	12-14	1.341	-1.751	0.989	0.978	0.016
	18-20	1.130	-1.610	0.986	0.972	0.014
April	00-02					
	06-08	1.394	-1.318	0.995	0.990	0.013
	12-14	1.850	-1.741	0.988	0.976	0.029
	18-20	1.959	-1.687	0.995	0.990	0.017
July	00-02					
	06-08	1.472	-1.090	0.988	0.976	0.021
	12-14	2.320	-1.853	0.995	0.990	0.019
	18-20	1.887	-1.629	0.993	0.986	0.016
October	00-02					
	06-08	1.246	-1.527	0.989	0.978	0.014
	12-14	1.349	-1.380	0.995	0.990	0.014
	18-20	1.254	-1.207	0.994	0.988	0.012
Average				0.992	0.984	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(5) Wiesbaden						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.809	-1.042	0.996	0.992	0.007
	06-08	0.906	-1.290	0.994	0.988	0.009
	12-14	1.339	-1.667	0.996	0.992	0.011
	18-20	1.016	-1.284	0.994	0.988	0.009
April	00-02	1.046	-0.599	0.996	0.992	0.010
	06-08	1.433	-1.214	0.991	0.982	0.020
	12-14	1.870	-1.593	0.992	0.984	0.025
	18-20	1.898	-1.461	0.994	0.988	0.019
July	00-02	1.365	-0.634	0.997	0.994	0.012
	06-08	1.592	-1.158	0.989	0.978	0.025
	12-14	2.304	-1.815	0.992	0.984	0.029
	18-20	2.065	-1.486	0.990	0.980	0.029
October	00-02	0.951	-0.651	0.998	0.996	0.007
	06-08	1.149	-1.172	0.990	0.980	0.017
	12-14	1.479	-1.370	0.993	0.986	0.019
	18-20	1.415	-1.093	0.997	0.994	0.011
Average				0.993	0.987	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(6) Spangdahlem						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.793	-1.083	0.995	0.990	0.007
	06-08	0.962	-1.364	0.990	0.980	0.010
	12-14	1.157	-1.514	0.993	0.986	0.011
	18-20	0.938	-1.191	0.996	0.992	0.007
April	00-02	1.035	-0.657	0.994	0.988	0.012
	06-08	1.353	-1.401	0.982	0.964	0.025
	12-14	2.003	-2.006	0.981	0.962	0.034
	18-20	1.903	-1.570	0.994	0.988	0.017
July	00-02	1.379	-0.787	0.993	0.986	0.017
	06-08	1.510	-1.435	0.986	0.972	0.025
	12-14	2.365	-2.164	0.989	0.978	0.033
	18-20	2.035	-1.646	0.996	0.992	0.018
October	00-02	0.854	-0.783	0.995	0.990	0.009
	06-08	1.110	-1.377	0.984	0.968	0.017
	12-14	1.341	-1.329	0.985	0.970	0.025
	18-20	1.127	-0.876	0.991	0.982	0.015
Average				0.990	0.981	0.018

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(7) Hahn						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.801	-1.231	0.998	0.996	0.004
	06-08	0.933	-1.471	0.987	0.974	0.012
	12-14	1.176	-1.713	0.993	0.986	0.012
	18-20	0.901	-1.341	0.996	0.992	0.006
April	00-02	0.992	-0.778	0.997	0.994	0.008
	06-08	1.210	-1.314	0.990	0.980	0.016
	12-14	1.890	-1.949	0.980	0.960	0.037
	18-20	1.798	-1.548	0.996	0.992	0.014
July	00-02	1.282	-0.772	0.995	0.990	0.012
	06-08	1.387	-1.270	0.988	0.976	0.021
	12-14	2.383	-2.096	0.991	0.982	0.032
	18-20	1.980	-1.607	0.994	0.988	0.023
October	00-02	0.888	-0.811	0.998	0.996	0.007
	06-08	1.111	-1.370	0.990	0.980	0.015
	12-14	1.403	-1.410	0.990	0.980	0.021
	18-20	1.168	-0.968	0.996	0.992	0.010
Average				0.992	0.985	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(8) Sembach

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.850	-1.039	0.994	0.988	0.006
	06-08	0.963	-1.261	0.996	0.992	0.007
	12-14	1.282	-1.632	0.992	0.984	0.012
	18-20	1.128	-1.323	0.992	0.984	0.010
April	00-02	1.098	-0.662	0.995	0.990	0.011
	06-08	1.354	-1.272	0.984	0.968	0.019
	12-14	1.982	-1.850	0.993	0.986	0.023
	18-20	1.930	-1.668	0.990	0.980	0.018
July	00-02	1.313	-0.652	0.991	0.982	0.018
	06-08	1.420	-1.139	0.986	0.972	0.025
	12-14	2.257	-1.915	0.993	0.986	0.027
	18-20	2.161	-1.646	0.996	0.992	0.021
October	00-02	1.056	-0.740	0.996	0.992	0.009
	06-08	1.294	-1.369	0.992	0.984	0.015
	12-14	1.459	-1.409	0.994	0.988	0.017
	18-20	1.483	-1.103	0.988	0.976	0.021
Average				0.992	0.984	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(9) Zweibrücken						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.763	-1.015	0.990	0.980	0.011
	06-08	0.969	-1.307	0.990	0.980	0.013
	12-14	1.268	-1.625	0.966	0.933	0.032
	18-20	1.180	-1.356	0.991	0.982	0.013
April	00-02	1.071	-0.607	0.995	0.990	0.012
	06-08	1.436	-1.235	0.976	0.953	0.033
	12-14	2.030	-1.811	0.971	0.943	0.049
	18-20	2.121	-1.650	0.992	0.984	0.027
July	00-02	1.296	-0.577	0.994	0.988	0.016
	06-08	1.677	-1.224	0.965	0.931	0.047
	12-14	2.586	-1.979	0.978	0.956	0.052
	18-20	2.225	-1.524	0.978	0.956	0.045
October	00-02	0.915	-0.650	0.995	0.990	0.010
	06-08	1.212	-1.249	0.969	0.939	0.031
	12-14	1.639	-1.472	0.973	0.947	0.042
	18-20	1.470	-1.072	0.990	0.980	0.022
Average				0.982	0.965	0.028

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(10) Sandhofen						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02					
	06-08	0.936	-1.419	0.993	0.986	0.008
	12-14	1.291	-1.668	0.990	0.980	0.014
	18-20	1.160	-1.449	0.986	0.972	0.017
April	00-02					
	06-08	1.419	-1.463	0.992	0.984	0.016
	12-14	1.835	-1.766	0.992	0.984	0.025
	18-20	1.661	-1.629	0.985	0.970	0.029
July	00-02					
	06-08	1.574	-1.201	0.989	0.978	0.020
	12-14	2.299	-1.870	0.991	0.982	0.030
	18-20	1.961	-1.531	0.992	0.984	0.027
October	00-02					
	06-08	1.258	-1.390	0.991	0.982	0.016
	12-14	1.304	-1.329	0.977	0.955	0.030
	18-20	1.521	-1.289	0.994	0.988	0.014
Average				0.989	0.979	0.021

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(11) Erding

Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.801	-1.035	0.994	0.988	0.008
	06-08	1.250	-1.545	0.997	0.994	0.007
	12-14	1.402	-1.584	0.988	0.976	0.020
	18-20	0.984	-1.159	0.995	0.990	0.008
April	00-02	0.822	-0.540	0.996	0.992	0.008
	06-08	1.331	-1.064	0.993	0.986	0.016
	12-14	1.773	-1.475	0.988	0.976	0.030
	18-20	1.664	-1.287	0.997	0.994	0.013
July	00-02	1.157	-0.617	0.999	0.998	0.007
	06-08	1.352	-0.915	0.990	0.980	0.021
	12-14	2.234	-1.545	0.996	0.992	0.021
	18-20	1.803	-1.219	0.993	0.986	0.020
October	00-02	0.790	-0.538	0.995	0.990	0.009
	06-08	1.307	-1.339	0.991	0.982	0.015
	12-14	1.549	-1.136	0.994	0.988	0.017
	18-20	1.036	-0.570	0.994	0.988	0.012
Average				0.994	0.988	0.015

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(12) Nürnberg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.757	-1.023	0.963	0.927	0.022
	06-08	1.058	-1.371	0.952	0.906	0.034
	12-14	1.444	-1.640	0.926	0.857	0.060
	18-20	0.933	-1.184	0.969	0.939	0.025
April	00-02	1.108	-0.816	0.981	0.962	0.024
	06-08	1.495	-1.282	0.942	0.887	0.053
	12-14	2.341	-1.896	0.969	0.939	0.055
	18-20	1.811	-1.353	0.969	0.939	0.043
July	00-02	1.324	-0.681	0.985	0.970	0.025
	06-08	1.593	-1.075	0.947	0.897	0.054
	12-14	2.773	-1.971	0.976	0.953	0.054
	18-20	2.207	-1.356	0.963	0.927	0.052
October	00-02	0.779	-0.569	0.971	0.943	0.021
	06-08	1.111	-1.106	0.948	0.899	0.040
	12-14	1.600	-1.228	0.954	0.910	0.052
	18-20	1.134	-0.820	0.975	0.951	0.028
Average				0.962	0.925	0.040

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(13) Grafenwöhr						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.941	-1.360	0.984	0.968	0.012
	06-08	1.032	-1.510	0.993	0.986	0.007
	12-14	1.202	-1.628	0.981	0.962	0.017
	18-20	1.066	-1.383	0.980	0.960	0.013
April	00-02	0.982	-0.735	0.996	0.992	0.008
	06-08	1.344	-1.414	0.942	0.887	0.014
	12-14	1.714	-1.727	0.986	0.972	0.026
	18-20	1.891	-1.580	0.994	0.988	0.019
July	00-02	1.399	-0.625	0.991	0.982	0.020
	06-08	1.424	-1.165	0.986	0.972	0.028
	12-14	2.360	-1.988	0.992	0.984	0.029
	18-20	1.908	-1.435	0.993	0.986	0.023
October	00-02	0.944	-0.798	0.996	0.992	0.009
	06-08	1.218	-1.408	0.989	0.978	0.018
	12-14	1.252	-1.128	0.984	0.968	0.024
	18-20	1.155	-0.874	0.993	0.986	0.012
Average				0.986	0.973	0.017

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explainted Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(14) Kitzingen						
Model	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.741	-0.904	0.981	0.962	0.007
	06-08	0.802	-1.141	0.984	0.968	0.011
	12-14	1.246	-1.532	0.982	0.964	0.022
	18-20	0.877	-1.116	0.989	0.978	0.010
April	00-02	1.300	-0.980	0.996	0.992	0.011
	06-08	1.490	-1.399	0.995	0.990	0.015
	12-14	1.699	-1.593	0.990	0.980	0.024
	18-20	1.828	-1.602	0.997	0.994	0.014
July	00-02	1.382	-0.735	0.991	0.982	0.020
	06-08	1.380	-1.095	0.992	0.984	0.016
	12-14	2.497	-2.108	0.995	0.990	0.026
	18-20	1.931	-1.474	0.998	0.996	0.014
October	00-02	0.876	-0.618	0.966	0.992	0.024
	06-08	1.243	-1.401	0.985	0.970	0.021
	12-14	1.057	-1.137	0.990	0.980	0.016
	18-20	1.326	-0.961	0.998	0.996	0.009
Average				0.991	0.982	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(15) Hanau						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.853	-1.276	0.972	0.945	0.016
	06-08	0.883	-1.185	0.997	0.995	0.005
	12-14	1.202	-1.473	0.991	0.982	0.013
	18-20	1.008	-1.215	0.990	0.980	0.010
April	00-02	1.009	-0.803	0.993	0.986	0.013
	06-08	1.414	1.315	0.989	0.978	0.015
	12-14	1.961	-1.816	0.994	0.988	0.021
	18-20	1.793	-1.571	0.995	0.990	0.019
July	00-02	1.283	-0.810	0.985	0.970	0.024
	06-08	1.409	-1.127	0.993	0.986	0.017
	12-14	2.069	-1.697	0.996	0.992	0.018
	18-20	1.718	-1.402	0.985	0.970	0.032
October	00-02	0.881	-0.537	0.989	0.978	0.015
	06-08	1.106	-1.247	0.985	0.970	0.017
	12-14	1.359	-1.340	0.991	0.982	0.019
	18-20	1.259	-1.136	0.996	0.992	0.010
Average				0.990	0.980	0.017

Table 6. Vaues of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(16) Rhein-Main						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.872	-1.084	0.987	0.974	0.014
	06-08	1.109	-1.429	0.974	0.949	0.026
	12-14	1.492	-1.655	0.974	0.949	0.036
	18-20	1.023	-1.233	0.986	0.972	0.017
April	00-02	1.180	-0.711	0.991	0.982	0.017
	06-08	1.560	-1.263	0.975	0.951	0.037
	12-14	2.270	-1.783	0.986	0.972	0.036
	18-20	1.859	-1.366	0.990	0.980	0.025
July	00-02	1.409	-0.701	0.993	0.986	0.017
	06-08	1.711	-1.154	0.970	0.941	0.043
	12-14	2.694	-1.913	0.985	0.970	0.041
	18-20	2.306	-1.502	0.983	0.966	0.038
October	00-02	0.812	-0.604	0.979	0.958	0.019
	06-08	1.192	-1.195	0.975	0.951	0.030
	12-14	1.696	-1.382	0.983	0.966	0.032
	18-20	1.295	-0.906	0.989	0.978	0.021
Average				0.982	0.965	0.028

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(17) Fulda						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.270	-1.887	0.995	0.990	0.007
	06-08	1.028	-1.614	0.995	0.990	0.007
	12-14	1.059	-1.624	0.969	0.939	0.014
	18-20	1.158	-1.756	0.985	0.970	0.010
April	00-02	0.805	-0.755	0.989	0.978	0.012
	06-08	1.142	-1.514	0.990	0.980	0.014
	12-14	1.647	-1.792	0.980	0.960	0.031
	18-20	1.514	-1.511	0.989	0.978	0.021
July	00-02	1.009	-0.751	0.994	0.988	0.012
	06-08	1.414	-1.389	0.988	0.976	0.021
	12-14	2.262	-1.990	0.995	0.990	0.022
	18-20	1.681	-1.431	0.986	0.972	0.025
October	00-02	1.041	-0.611	0.978	0.956	0.023
	06-08	1.277	-1.831	0.986	0.972	0.011
	12-14	1.322	-1.399	0.990	0.980	0.017
	18-20	1.282	-1.239	0.990	0.980	0.015
Average				0.987	0.975	0.016

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (RMSE) for Each German Station and Time Period in the Model Study (Contd)

6(18) Berlin						
Month	Time (LST)	a	b	ρ	ρ	rmse
January	00-02	0.766	-0.978	0.985	0.970	0.014
	06-08	1.002	-1.213	0.993	0.986	0.011
	12-14	1.248	-1.443	0.976	0.953	0.028
	18-20	1.008	-1.117	0.994	0.988	0.012
April	00-02	0.987	-0.556	0.992	0.984	0.014
	06-08	1.321	-1.064	0.991	0.982	0.020
	12-14	1.770	-1.415	0.982	0.964	0.035
	18-20	1.839	-1.328	0.992	0.984	0.024
July	00-02	1.213	-0.569	0.988	0.976	0.020
	06-08	1.656	-1.197	0.989	0.978	0.025
	12-14	2.303	-1.866	0.984	0.968	0.037
	18-20	2.324	-1.587	0.993	0.986	0.024
October	00-02	0.874	-0.598	0.991	0.982	0.013
	06-08	1.164	-1.165	0.983	0.966	0.022
	12-14	1.527	-1.322	0.986	0.972	0.027
	18-20	1.313	-1.001	0.993	0.986	0.016
Average				0.988	0.977	0.021

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(19) Illesheim						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02					
	06-08	1.105	-1.412	0.992	0.984	0.013
	12-14	1.486	-1.753	0.985	0.970	0.021
	18-20	1.125	-1.372	0.993	0.986	0.012
April	00-02					
	06-08	1.524	-1.481	0.995	0.990	0.015
	12-14	1.835	-1.818	0.972	0.945	0.043
	18-20	1.586	-1.582	0.985	0.970	0.029
July	00-02					
	06-08	1.414	-1.000	0.991	0.982	0.020
	12-14	2.461	-1.926	0.994	0.988	0.029
	18-20	2.129	-1.599	0.985	0.970	0.023
October	00-02					
	06-08	1.537	-1.453	0.994	0.988	0.019
	12-14	1.372	-1.196	0.981	0.962	0.033
	18-20	1.397	-1.180	0.994	0.988	0.014
Average				0.988	0.977	0.023

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(20) München						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.779	-0.984	0.959	0.920	0.024
	06-08	1.008	-1.219	0.978	0.956	0.022
	12-14	1.675	-1.520	0.974	0.949	0.040
	18-20	1.083	-1.142	0.980	0.960	0.024
April	00-02	0.993	-0.716	0.989	0.978	0.017
	06-08	1.484	-1.206	0.972	0.945	0.035
	12-14	2.353	-1.787	0.983	0.966	0.036
	18-20	1.888	-1.435	0.982	0.964	0.035
July	00-02	1.275	-0.738	0.983	0.966	0.025
	06-08	1.617	-0.979	0.964	0.929	0.046
	12-14	2.625	-1.638	0.974	0.949	0.048
	18-20	2.238	-1.320	0.975	0.951	0.042
October	00-02	0.758	-0.381	0.982	0.964	0.016
	06-08	1.252	-1.095	0.965	0.931	0.028
	12-14	1.720	-1.088	0.975	0.951	0.039
	18-20	1.354	-0.720	0.980	0.960	0.029
Average				0.976	0.953	0.03[illegible]

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(21) Freiburg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.870	-1.078	0.967	0.935	0.024
	06-08	0.938	-1.203	0.979	0.958	0.018
	12-14	1.466	-1.570	0.933	0.870	0.057
	18-20	1.155	-1.369	0.951	0.904	0.036
April	00-02	1.284	-1.002	0.994	0.988	0.016
	06-08	1.429	-1.235	0.947	0.897	0.051
	12-14	2.434	-1.906	0.960	0.922	0.057
	18-20	2.419	-1.888	0.981	0.962	0.043
July	00-02	1.625	-0.722	0.984	0.968	0.030
	06-08	1.818	-0.978	0.952	0.906	0.056
	12-14	3.016	-1.764	0.937	0.878	0.076
	18-20	2.722	-1.636	0.973	0.947	0.054
October	00-02	0.795	-0.600	0.981	0.962	0.018
	06-08	1.622	-1.385	0.968	0.937	0.035
	12-14	1.894	-1.418	0.966	0.933	0.045
	18-20	1.679	-1.168	0.978	0.956	0.031
Average				0.966	0.933	0.040

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(22) Magdeburg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.857	-1.157	0.971	0.943	0.021
	06-08	0.914	-1.377	0.975	0.951	0.017
	12-14	1.727	-1.764	0.977	0.955	0.036
	18-20	1.017	-1.166	0.960	0.922	0.031
April	00-02	0.953	-0.677	0.968	0.937	0.027
	06-08	1.130	-1.086	0.983	0.966	0.022
	12-14	1.998	-1.697	0.984	0.968	0.037
	18-20	2.175	-1.666	0.987	0.974	0.032
July	00-02	1.342	-0.761	0.991	0.982	0.020
	06-08	1.740	-1.285	0.971	0.943	0.045
	12-14	2.492	-1.809	0.982	0.964	0.048
	18-20	2.407	-1.599	0.980	0.960	0.049
October	00-02	0.715	-0.600	0.972	0.945	0.019
	06-08	1.476	-1.379	0.989	0.978	0.019
	12-14	1.746	-1.445	0.982	0.964	0.035
	18-20	1.179	-0.905	0.977	0.955	0.028
Average				0.978	0.957	0.030

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(23) Emden						
Model	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.829	-0.966	0.987	0.974	0.015
	06-08	0.936	-1.153	0.962	0.925	0.028
	12-14	1.679	-1.752	0.992	0.984	0.019
	18-20	1.077	-1.331	0.966	0.933	0.030
April	00-02	0.781	-0.567	0.985	0.970	0.016
	06-08	1.604	-1.303	0.990	0.980	0.023
	12-14	2.526	-1.904	0.980	0.960	0.035
	18-20	1.599	-1.191	0.988	0.976	0.026
July	00-02	1.282	-0.829	0.977	0.955	0.030
	06-08	1.736	-1.178	0.980	0.960	0.037
	12-14	3.019	-2.090	0.996	0.992	0.025
	18-20	1.980	-1.310	0.985	0.970	0.036
October	00-02	0.774	-0.601	0.966	0.933	0.023
	06-08	1.268	-1.197	0.976	0.953	0.030
	12-14	1.773	-1.340	0.966	0.933	0.050
	18-20	1.759	-1.309	0.995	0.990	0.016
Average				0.981	0.962	0.027

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(24) Hamburg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.720	-1.020	0.973	0.947	0.018
	06-08	0.915	-1.260	0.970	0.941	0.022
	12-14	1.598	-1.648	0.951	0.904	0.041
	18-20	1.151	-1.350	0.972	0.945	0.029
April	00-02	0.991	-0.699	0.977	0.955	0.024
	06-08	1.624	-1.373	0.955	0.912	0.049
	12-14	2.329	-1.822	0.982	0.964	0.041
	18-20	2.286	-1.667	0.965	0.931	0.046
July	00-02	1.508	-0.928	0.981	0.962	0.032
	06-08	2.101	-1.659	0.965	0.931	0.057
	12-14	2.985	-2.268	0.985	0.970	0.048
	18-20	2.562	-1.803	0.970	0.941	0.054
October	00-02	0.952	-0.769	0.972	0.945	0.026
	06-08	1.570	-1.506	0.970	0.941	0.036
	12-14	2.032	-1.682	0.971	0.943	0.052
	18-20	1.553	-1.273	0.968	0.937	0.039
Average				0.971	0.942	0.038

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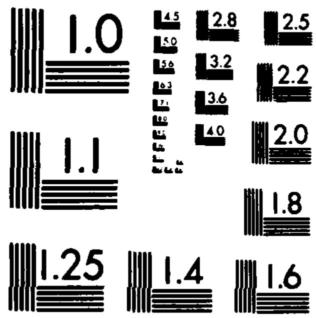

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Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(25) Warnemünde						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.822	-1.119	0.984	0.968	0.015
	06-08	1.122	-1.448	0.967	0.935	0.026
	12-14	1.608	-1.727	0.973	0.947	0.028
	18-20	0.947	-1.242	0.975	0.951	0.022
April	00-02	0.809	-0.545	0.988	0.976	0.014
	06-08	1.504	-1.371	0.990	0.980	0.019
	12-14	1.973	-1.605	0.979	0.958	0.028
	18-20	2.072	-1.532	0.977	0.955	0.033
July	00-02	1.629	-0.889	0.985	0.970	0.029
	06-08	2.040	-1.540	0.978	0.956	0.043
	12-14	2.652	-1.851	0.983	0.966	0.042
	18-20	2.188	-1.485	0.976	0.953	0.046
October	00-02	0.872	-0.675	0.988	0.976	0.015
	06-08	1.653	-1.567	0.984	0.968	0.026
	12-14	1.998	-1.696	0.988	0.976	0.031
	18-20	1.382	-1.118	0.986	0.972	0.023
Average				0.981	0.963	0.028

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(26) Münster						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.773	-1.005	0.943	0.889	0.029
	06-08	1.168	-1.377	0.973	0.947	0.028
	12-14	1.524	-1.587	0.959	0.920	0.046
	18-20	1.215	-1.352	0.951	0.904	0.042
April	00-02	1.072	-0.676	0.976	0.953	0.026
	06-08	1.595	-1.340	0.976	0.953	0.032
	12-14	2.163	-1.719	0.966	0.933	0.058
	18-20	2.388	-1.816	0.976	0.953	0.054
July	00-02	1.375	-0.840	0.960	0.922	0.042
	06-08	1.551	-1.271	0.939	0.882	0.059
	12-14	2.739	-2.085	0.968	0.937	0.066
	18-20	2.402	-1.731	0.973	0.947	0.055
October	00-02	0.728	-0.407	0.954	0.910	0.025
	06-08	1.275	-1.133	0.966	0.933	0.034
	12-14	1.780	-1.317	0.971	0.943	0.045
	18-20	1.523	-0.997	0.975	0.951	0.035
Average				0.964	0.930	0.042

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(27) Hannover						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.910	-1.224	0.954	0.910	0.029
	06-08	1.093	-1.392	0.963	0.927	0.030
	12-14	1.670	-1.792	0.913	0.834	0.075
	18-20	1.055	-1.246	0.950	0.903	0.035
April	00-02	1.096	-0.755	0.961	0.924	0.035
	06-08	1.595	-1.423	0.948	0.899	0.054
	12-14	2.326	-1.853	0.968	0.937	0.057
	18-20	2.273	-1.700	0.960	0.922	0.065
July	00-02	1.382	-0.852	0.980	0.960	0.030
	06-08	1.948	-1.527	0.948	0.899	0.065
	12-14	2.830	-2.211	0.967	0.935	0.070
	18-20	2.540	-1.796	0.960	0.922	0.067
October	00-02	0.812	-0.633	0.974	0.949	0.021
	06-08	1.692	-1.564	0.964	0.929	0.046
	12-14	1.966	-1.624	0.950	0.903	0.066
	18-20	1.468	-1.134	0.962	0.925	0.042
Average				0.958	0.917	0.049

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(28) Köln/Bonn						
Model	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.920	-1.057	0.963	0.927	0.028
	06-08	1.417	-1.575	0.991	0.982	0.019
	12-14	1.820	-1.727	0.963	0.927	0.054
	18-20	1.401	-1.400	0.979	0.958	0.031
April	00-02	1.402	-0.999	0.992	0.984	0.019
	06-08	1.664	-1.494	0.957	0.916	0.054
	12-14	2.411	-1.885	0.973	0.947	0.055
	18-20	2.489	-1.842	0.978	0.956	0.053
July	00-02	1.614	-0.855	0.988	0.976	0.025
	06-08	1.765	-1.297	0.962	0.925	0.052
	12-14	2.983	-2.085	0.974	0.949	0.057
	18-20	2.566	-1.716	0.966	0.933	0.063
October	00-02	1.157	-0.715	0.955	0.912	0.038
	06-08	1.522	-1.201	0.962	0.925	0.047
	12-14	1.977	-1.334	0.972	0.945	0.048
	18-20	1.592	-1.085	0.984	0.968	0.030
Average				0.973	0.946	0.042

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(29) Schleswig						
Model	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.891	-1.241	0.972	0.945	0.022
	06-08	1.022	-1.446	0.980	0.960	0.020
	12-14	1.604	-1.833	0.984	0.968	0.027
	18-20	1.020	-1.469	0.982	0.964	0.014
April	00-02	0.934	-0.642	0.981	0.962	0.020
	06-08	1.864	-1.501	0.959	0.920	0.040
	12-14	2.494	-2.023	0.983	0.966	0.041
	18-20	2.165	-1.570	0.980	0.960	0.031
July	00-02	1.688	-1.023	0.969	0.939	0.040
	06-08	2.104	-1.496	0.966	0.933	0.053
	12-14	2.771	-2.067	0.968	0.937	0.067
	18-20	2.470	-1.583	0.976	0.953	0.050
October	00-02	0.930	-0.891	0.971	0.943	0.026
	06-08	1.678	-1.567	0.975	0.951	0.028
	12-14	2.387	-2.080	0.986	0.972	0.038
	18-20	1.690	-1.399	0.979	0.958	0.029
Average				0.976	0.952	0.034

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(30) Kassel						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.226	-1.522	0.942	0.887	0.043
	06-08	1.350	-1.778	0.973	0.947	0.030
	12-14	1.853	-2.007	0.969	0.939	0.046
	18-20	1.426	-1.694	0.963	0.927	0.040
April	00-02	1.205	-0.869	0.984	0.968	0.024
	06-08	1.632	-1.359	0.962	0.925	0.048
	12-14	2.356	-1.767	0.984	0.968	0.037
	18-20	2.326	-1.660	0.981	0.962	0.039
July	00-02	1.717	-1.008	0.970	0.941	0.043
	06-08	1.751	-1.223	0.950	0.903	0.059
	12-14	2.599	-1.880	0.968	0.937	0.063
	18-20	2.397	-1.609	0.975	0.951	0.051
October	00-02	1.102	-1.006	0.959	0.920	0.036
	06-08	1.417	-1.529	0.971	0.943	0.033
	12-14	1.948	-1.595	0.970	0.941	0.048
	18-20	1.685	-1.281	0.973	0.947	0.043
Average				0.969	0.938	0.043

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(31) Kaltennordheim						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.638	-1.355	0.970	0.941	0.013
	06-08	0.786	-1.491	0.970	0.941	0.049
	12-14	1.453	-2.084	0.945	0.893	0.037
	18-20	0.891	-1.457	0.974	0.949	0.015
April	00-02	0.758	-0.396	0.979	0.958	0.017
	06-08	1.236	-1.235	0.970	0.941	0.032
	12-14	1.979	-1.669	0.986	0.972	0.032
	18-20	1.496	-1.308	0.982	0.964	0.024
July	00-02	0.942	-0.466	0.980	0.960	0.021
	06-08	1.346	-1.008	0.950	0.903	0.047
	12-14	2.632	-1.981	0.972	0.945	0.056
	18-20	1.884	-1.314	0.966	0.933	0.048
October	00-02	0.573	-0.670	0.976	0.953	0.014
	06-08	0.876	-1.209	0.933	0.870	0.028
	12-14	1.572	-1.486	0.960	0.922	0.032
	18-20	1.042	-1.022	0.971	0.943	0.026
Average				0.968	0.937	0.031

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(32) Dresden						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	0.809	-0.998	0.977	0.955	0.018
	06-08	0.880	-1.143	0.968	0.937	0.022
	12-14	1.370	-1.420	0.948	0.899	0.047
	18-20	0.858	-1.025	0.969	0.939	0.023
April	00-02	0.886	-0.622	0.984	0.968	0.018
	06-08	1.418	-1.320	0.977	0.955	0.033
	12-14	2.134	-1.777	0.982	0.964	0.040
	18-20	1.884	-1.480	0.990	0.980	0.026
July	00-02	1.138	-0.525	0.986	0.972	0.021
	06-08	1.526	-1.052	0.978	0.956	0.035
	12-14	2.729	-1.886	0.985	0.970	0.039
	18-20	2.176	-1.370	0.976	0.953	0.044
October	00-02	0.744	-0.545	0.979	0.958	0.018
	06-08	1.277	-1.099	0.970	0.941	0.034
	12-14	1.720	-1.321	0.979	0.958	0.037
	18-20	1.255	-0.903	0.981	0.962	0.027
Average				0.977	0.954	0.030

Table 6. Values of Simplified Linear Model Parameters a and b, Along With the Linear Correlation Coefficients (ρ), Explained Variations (ρ^2), and Root Mean Square Errors (rmse) for Each German Station and Time Period in the Model Study (Contd)

6(33) Würzburg						
Month	Time (LST)	a	b	ρ	ρ^2	rmse
January	00-02	1.097	-1.286	0.955	0.912	0.035
	06-08	1.321	-1.506	0.982	0.964	0.025
	12-14	1.715	-1.813	0.978	0.956	0.036
	18-20	1.317	-1.427	0.974	0.949	0.028
April	00-02	1.097	-0.538	0.964	0.929	0.032
	06-08	1.609	-1.130	0.977	0.955	0.034
	12-14	2.367	-1.687	0.987	0.974	0.037
	18-20	2.368	-1.548	0.988	0.976	0.031
July	00-02	1.289	-0.507	0.972	0.945	0.031
	06-08	1.866	-1.070	0.975	0.951	0.041
	12-14	3.101	-2.012	0.989	0.978	0.039
	18-20	2.596	-1.495	0.976	0.953	0.049
October	00-02	0.784	-0.637	0.955	0.912	0.027
	06-08	1.314	-1.397	0.960	0.922	0.036
	12-14	1.987	-1.475	0.983	0.966	0.034
	18-20	1.700	-1.183	0.979	0.958	0.035
Average				0.975	0.950	0.034

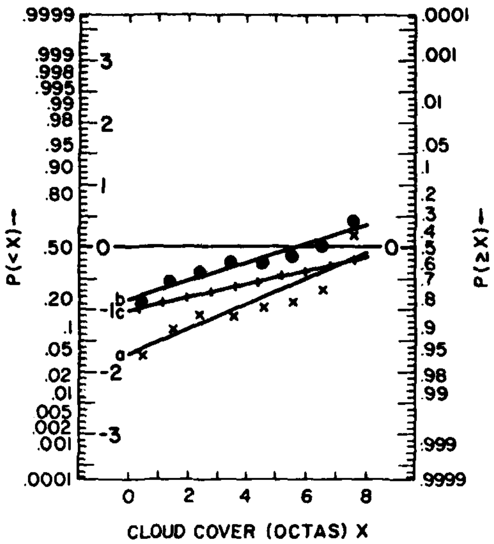


Figure 15. Simplified Linear Model Cumulative Probability Estimates of Fractional Cloud Cover for (a) The "Worst" Model Case (Hannover, January, 12-14 LST), (b) The "Average" Model Case (Dresden, October, 18-20 LST), and (c) "Best" Model Case (Heidelberg, January, 00-02 LST) Over Germany, Compared With Data

Values of P_0 were taken from Figures 18a-18p and of r from Figure 19. The rms errors between the Model B estimates and the data averaged 0.04, varying with station from 0.03 to 0.05. There was a difference in rms error depending on the sky cover itself, with the least error for clear and the most for overcast. The median rms error was found at Heidelberg in April, for 18-20 LST. Figure 20 compares the actual data with model results, the dots being the data and the solid line the model. This figure also shows the Model B estimates of the probability distribution over 1 percent of the sky dome and over 10 times the sky dome. Whereas the small area is characterized by a distinct U-shaped distribution, the large area has a bell-shaped distribution, and is rarely all clear or all overcast.

3.4.3 ANALYSIS OF GERMAN RESULTS

Unlike the Korean stations, the German stations are located in hilly regions as well as flatter areas. In fact, Figure 14 reveals that the greatest concentration of reporting stations is in the central and southern part of West Germany, a very hilly region. Here, the mountains are much like the Appalachians of the

Table 7. Observed Values and Simplified Linear Model Values for the Cumulative Frequency of Sky Cover and the Differences in These Values, for the Worst (a), Average (b), and Best (c) Simplified Linear Model Cases in Germany

Sky Cover Proportion	Observed Frequency (Cumulative)	Model Frequency (Cumulative)	Difference
(a) Hannover - January, 12-14 LST - "Worst" Case			
0.0625	0.044	0.046	-0.002
0.1875	0.088	0.070	0.018
0.3125	0.124	0.102	0.022
0.4375	0.143	0.144	-0.001
0.5625	0.162	0.197	-0.035
0.6875	0.186	0.260	-0.074
0.8125	0.242	0.332	-0.090
0.9375	0.582	0.411	0.171
(b) Dresden - October, 18-20 LST - "Average" Case			
0.0625	0.189	0.205	-0.016
0.1875	0.267	0.252	0.015
0.3125	0.321	0.305	0.016
0.4375	0.383	0.362	0.021
0.5625	0.415	0.422	-0.007
0.6875	0.448	0.484	-0.036
0.8125	0.509	0.546	-0.037
0.9375	0.651	0.608	0.043
(c) Heidelberg - January, 00-02 LST - "Best" Case			
0.05	0.162	0.161	0.001
0.15	0.179	0.183	-0.004
0.25	0.207	0.206	0.001
0.35	0.235	0.230	0.005
0.45	0.259	0.256	0.003
0.55	0.281	0.284	-0.003
0.65	0.307	0.313	-0.006
0.75	0.337	0.343	-0.006
0.85	0.379	0.375	0.004
0.95	0.411	0.407	0.004

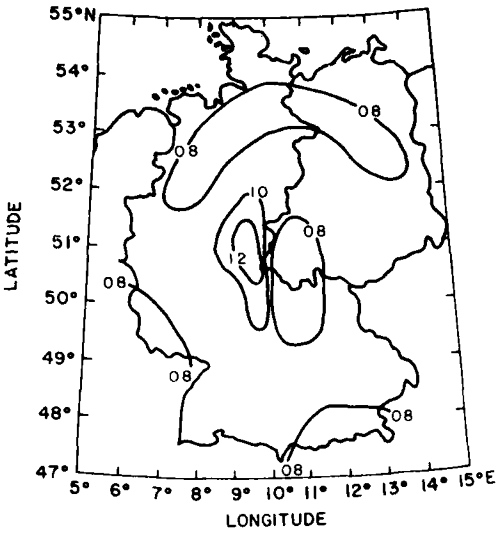


Figure 16a. January 00-02 LST

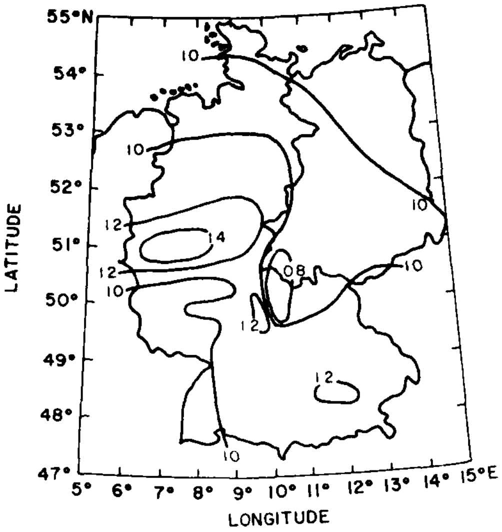


Figure 16b. January 06-08 LST

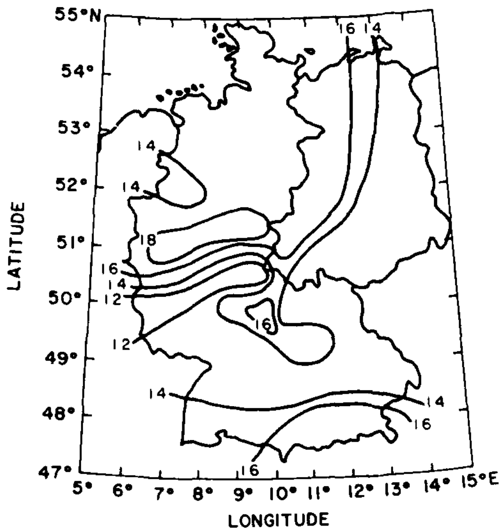


Figure 16c. January 12-14 LST

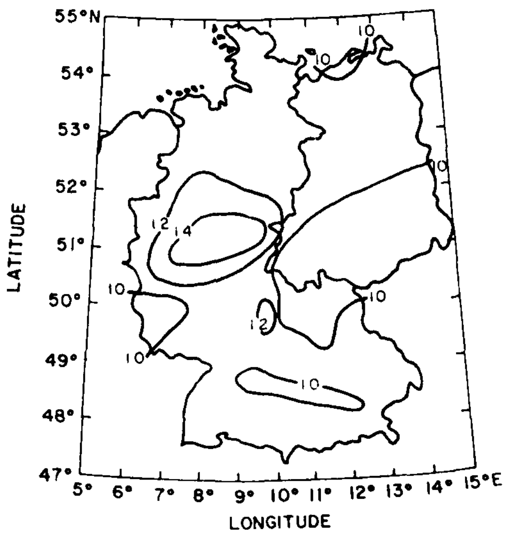


Figure 16d. January 18-20 LST

Figure 16. SLM Parameter a, Over Germany. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

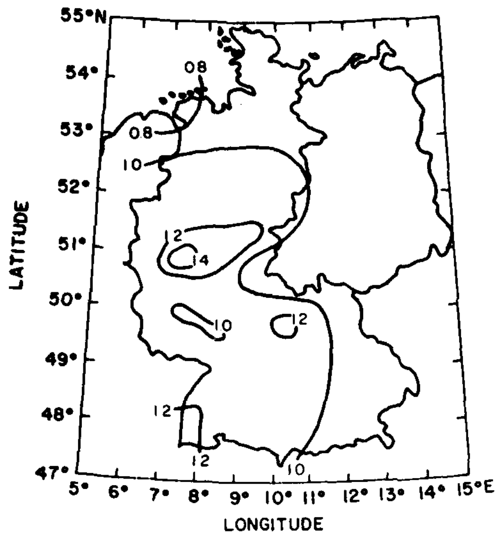


Figure 16e. April 00-02 LST

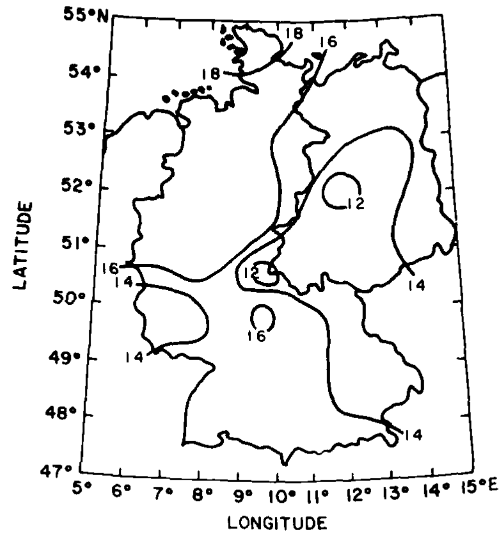


Figure 16f. April 06-08 LST

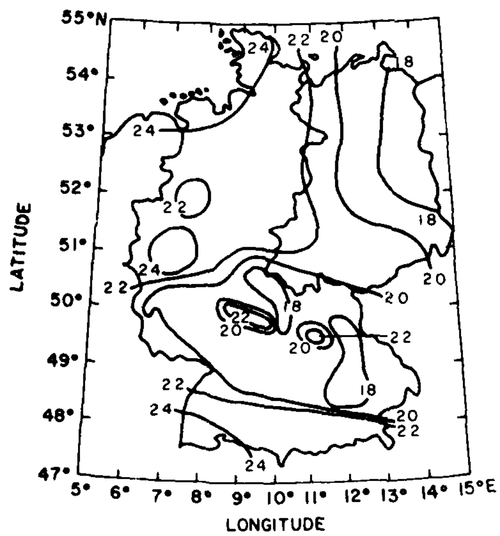


Figure 16g. April 12-14 LST

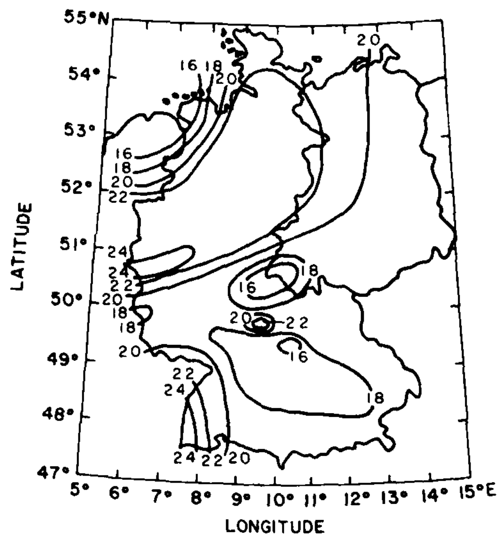


Figure 16h. April 18-20 LST

Figure 16. SLM Parameter a, Over Germany. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

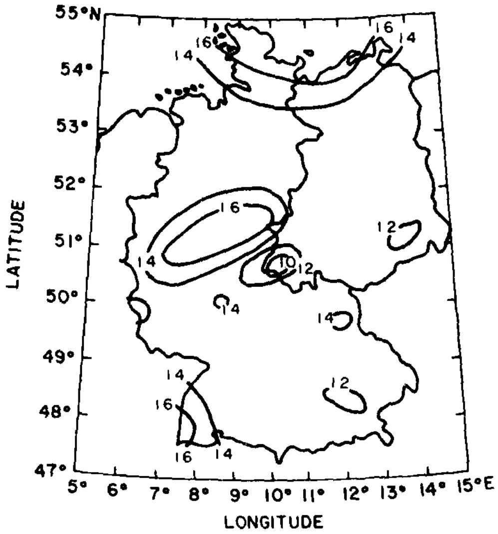


Figure 16i. July 00-02 LST

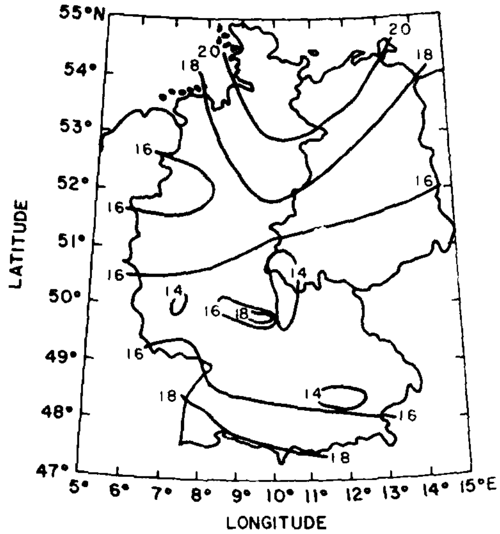


Figure 16j. July 06-08 LST

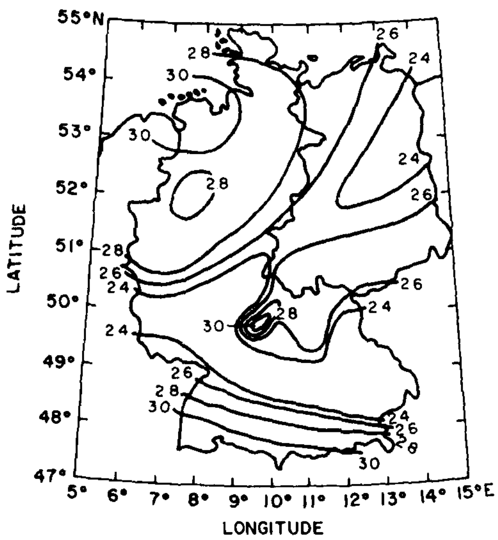


Figure 16k. July 12-14 LST

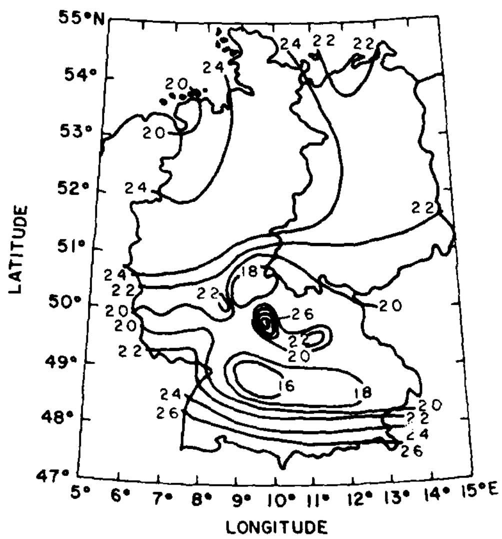


Figure 16l. July 18-20 LST

Figure 16. SLM Parameter a, Over Germany. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

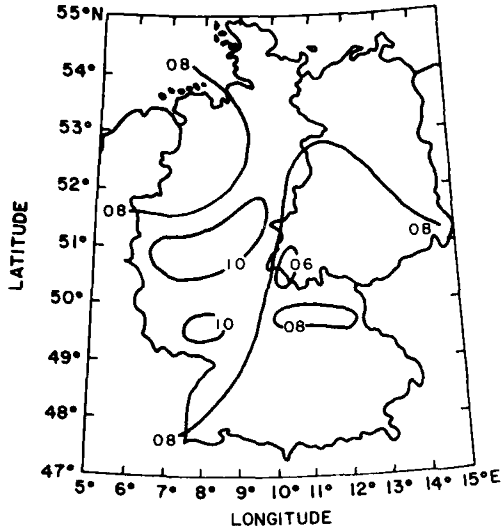


Figure 16m. October 00-02 LST

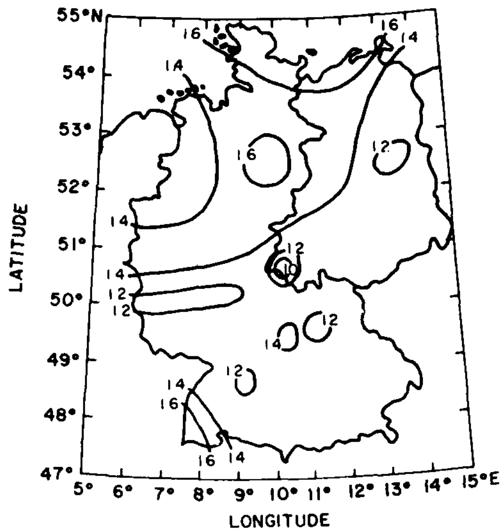


Figure 16n. October 06-08 LST

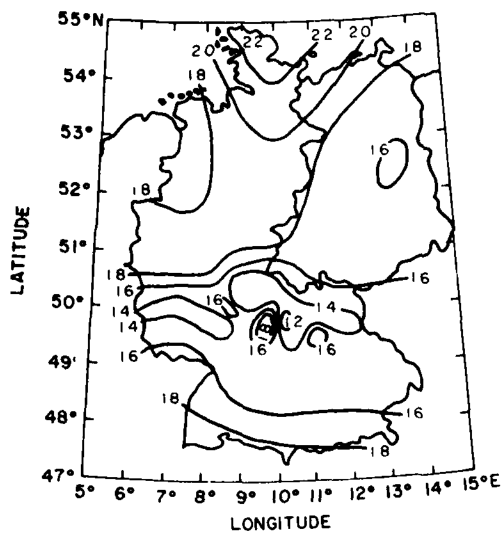


Figure 16o. October 12-14 LST

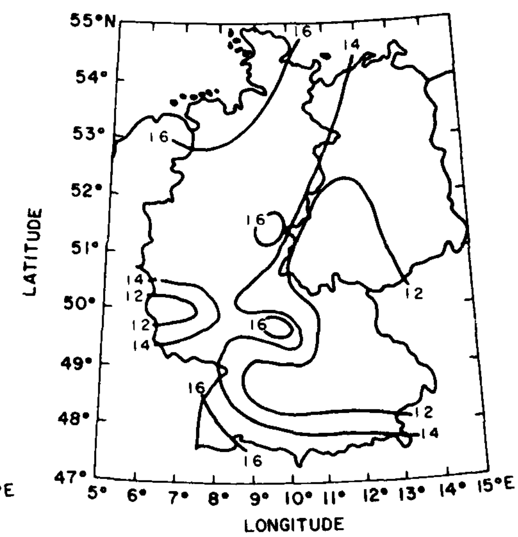


Figure 16p. October 18-20 LST

Figure 16. SLM Parameter a, Over Germany. The larger the value of a, the greater the rate of increase of the cumulative probability with increasing cloudiness

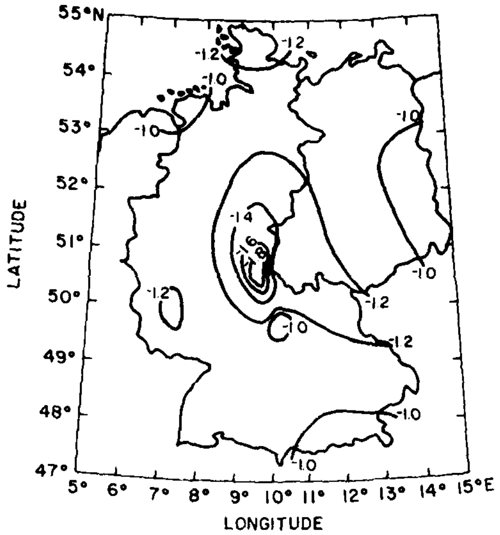


Figure 17a. January 00-02 LST. In this case, the frequency of clear skies ranges from 4 percent in the east central part of West Germany to 17 percent in the extreme northwest, eastern, and southern portions of the map

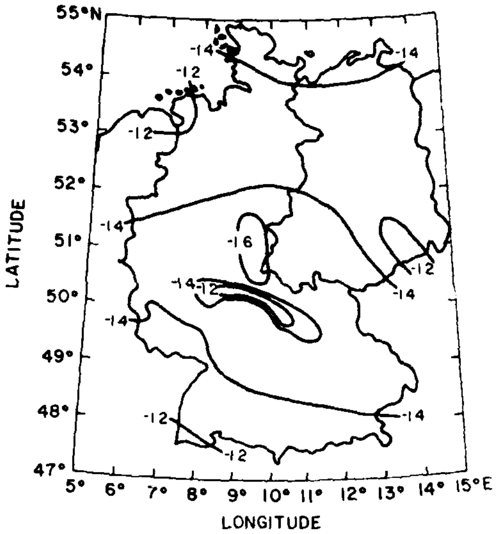


Figure 17b. January 06-08 LST

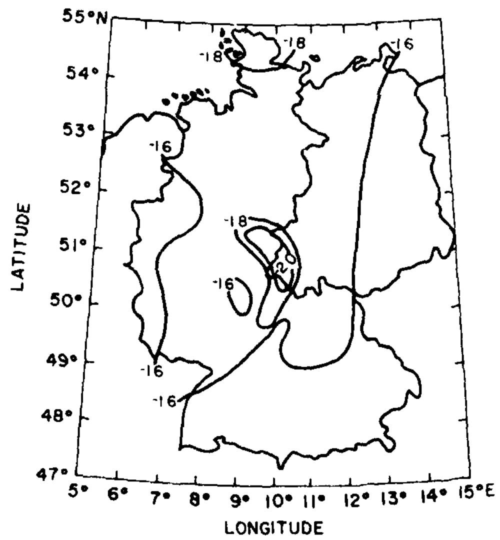


Figure 17c. January 12-14 LST

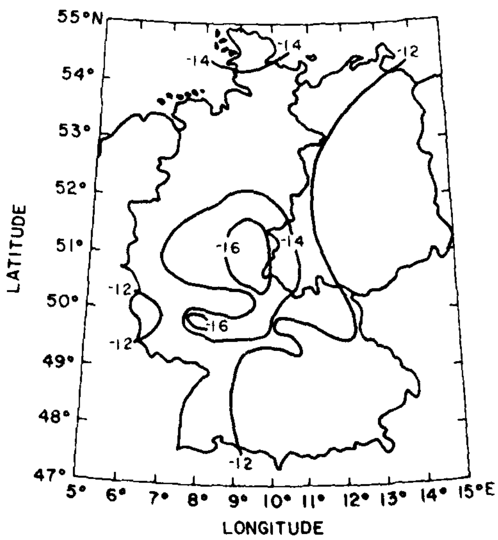


Figure 17d. January 18-20 LST

Figure 17. SLM Parameter b, Over Germany. This parameter is the END of the probability of clear

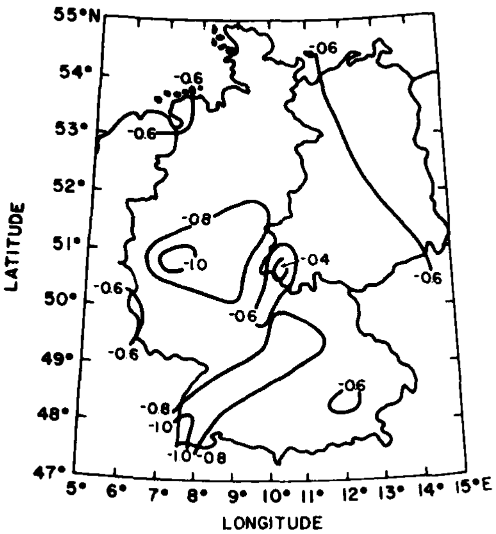


Figure 17e. April 00-02 LST

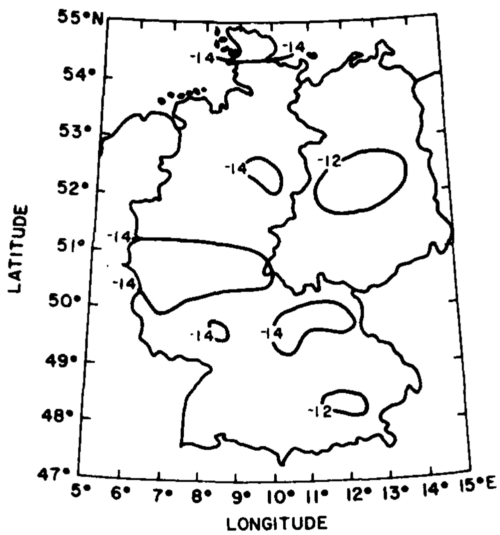


Figure 17f. April 06-08 LST

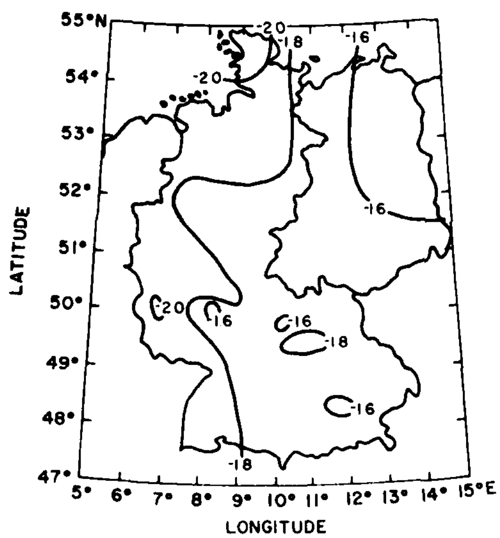


Figure 17g. April 12-14 LST

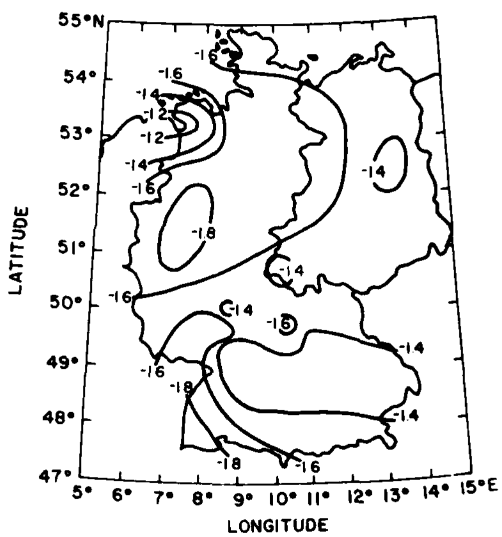


Figure 17h. April 18-20 LST

Figure 17. SLM Parameter b, Over Germany. This parameter is the END of the probability of clear

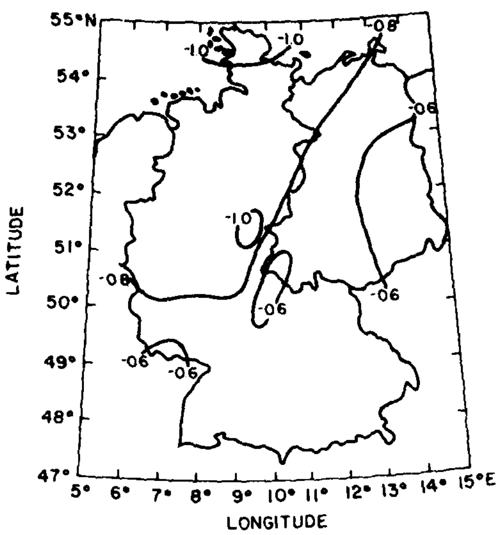


Figure 17i. July 00-02 LST

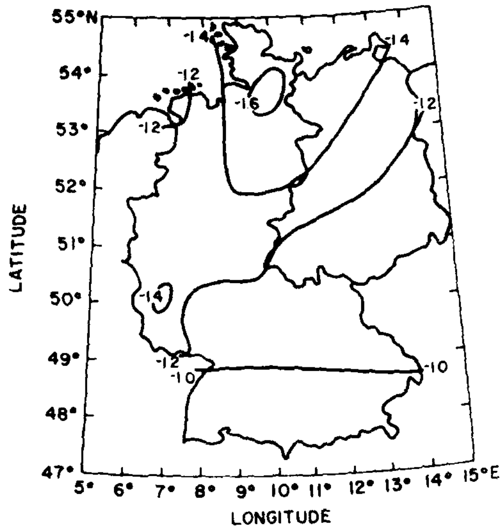


Figure 17j. July 06-08 LST

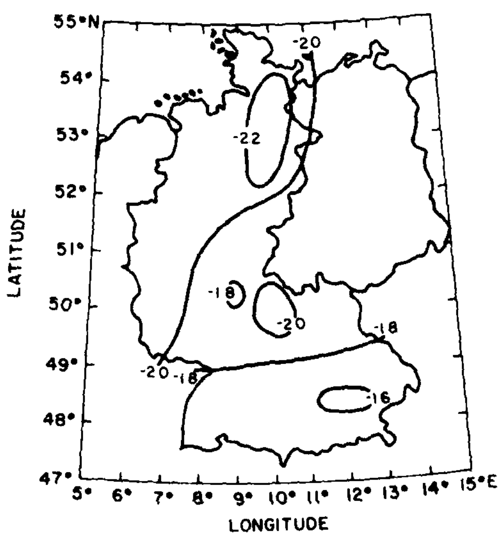


Figure 17k. July 12-14 LST

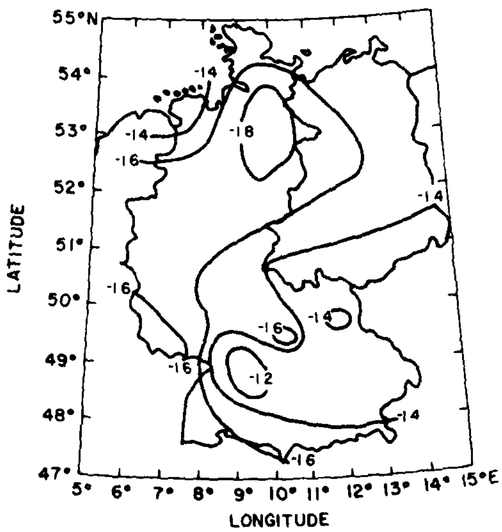


Figure 17l. July 18-20 LST

Figure 17. SLM Parameter b, Over Germany. This parameter is the END of the probability of clear

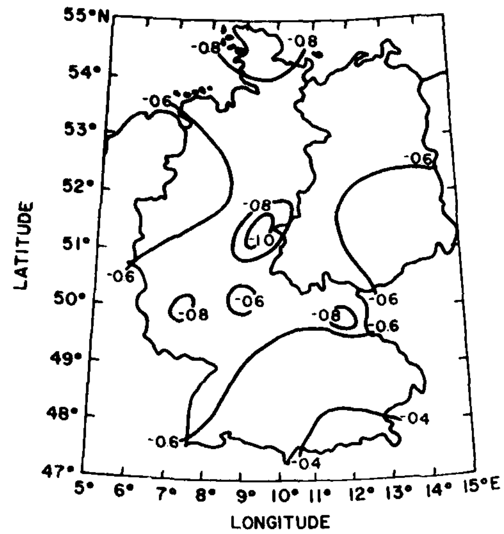


Figure 17m. October 00-02 LST

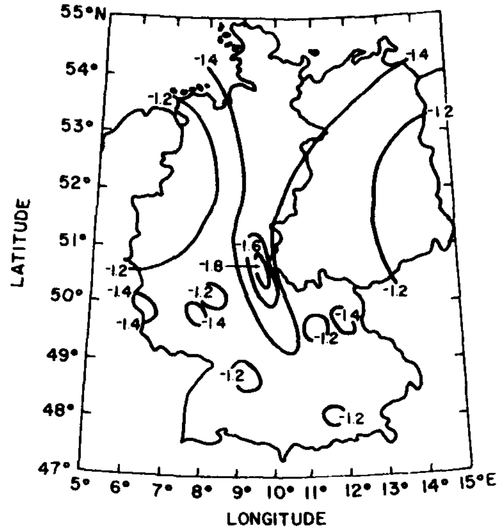


Figure 17n. October 06-08 LST

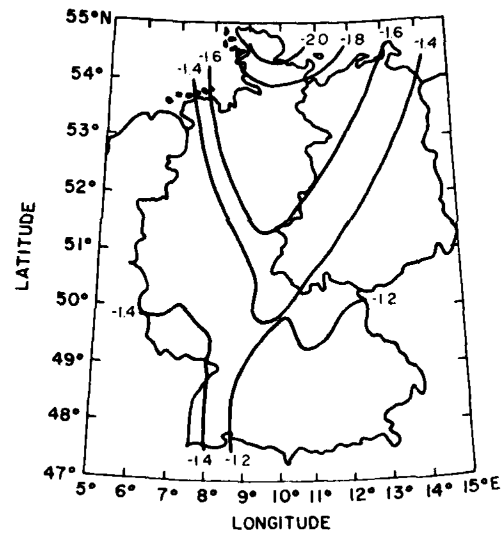


Figure 17o. October 12-14 LST

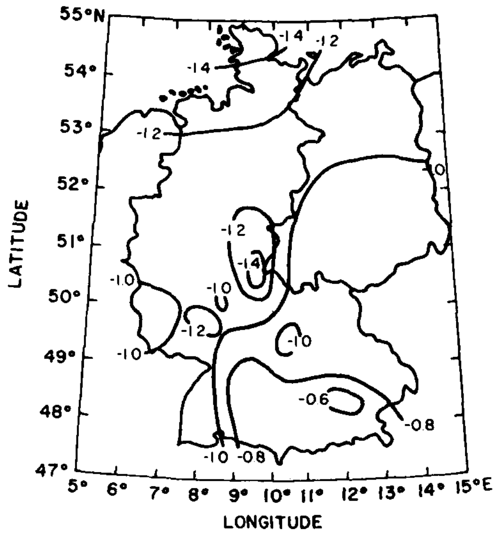


Figure 17p. October 18-20 LST

Figure 17. SLM Parameter b, Over Germany. This parameter is the END of the probability of clear

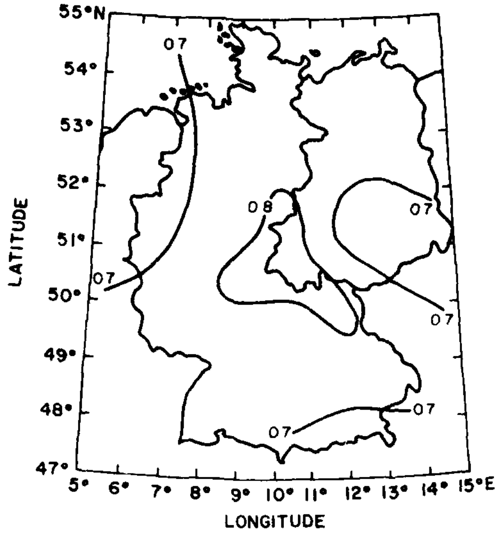


Figure 18a. Mean Sky Cover P_o in January, 00-02 LST, Over Germany

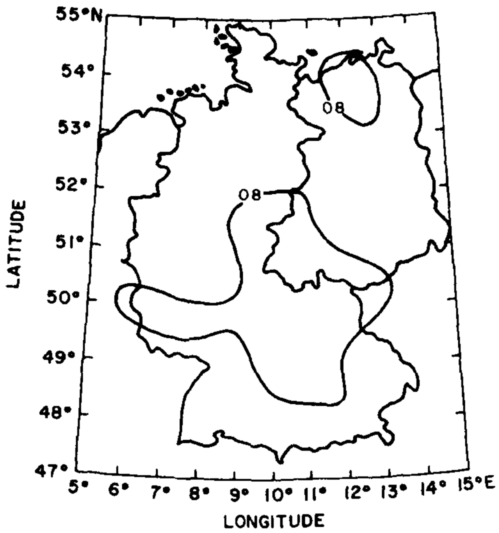


Figure 18b. Mean Sky Cover P_o in January, 06-08 LST, Over Germany

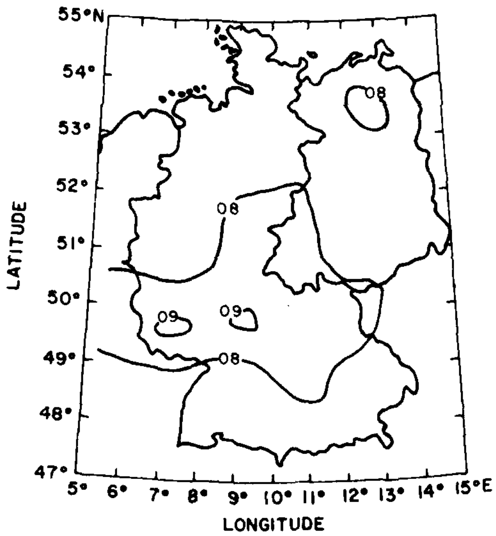


Figure 18c. Mean Sky Cover P_o in January, 12-14 LST, Over Germany

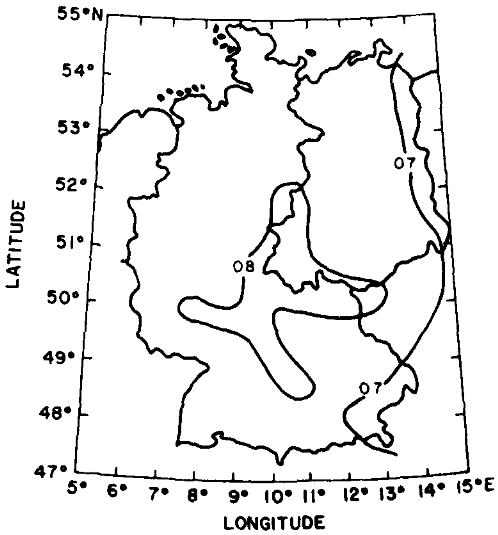


Figure 18d. Mean Sky Cover P_o in January, 18-20 LST, Over Germany

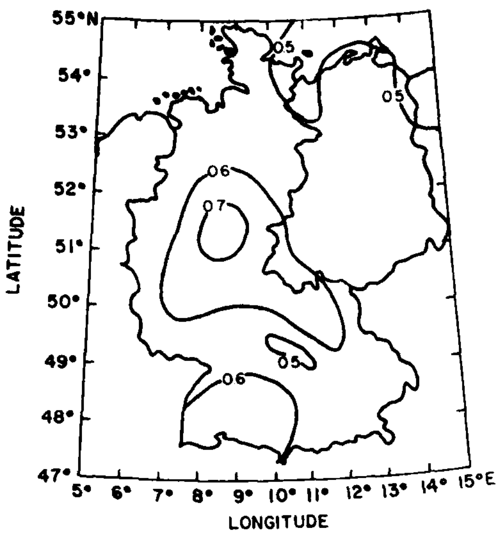


Figure 18e. Mean Sky Cover P_o in April, 00-02 LST, Over Germany

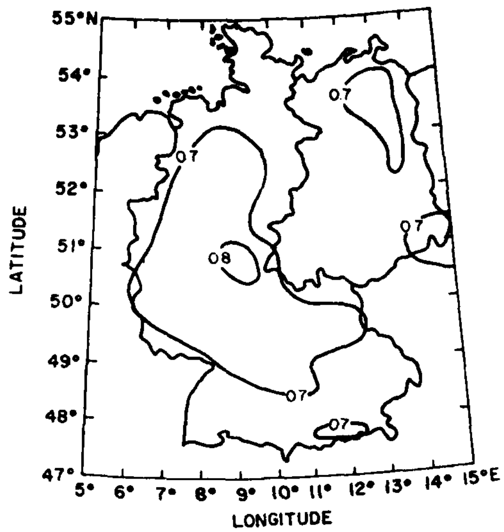


Figure 18f. Mean Sky Cover P_o in April, 06-08 LST, Over Germany

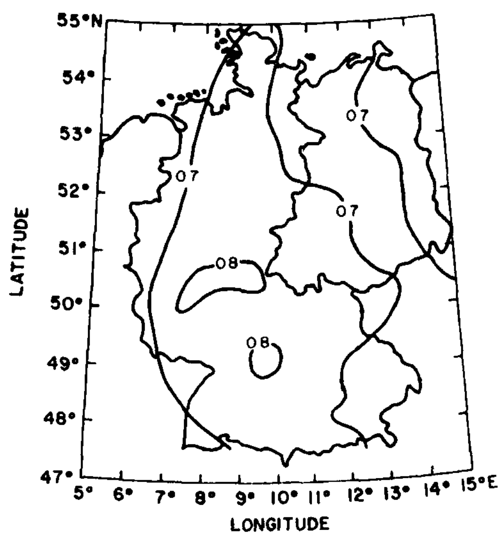


Figure 18g. Mean Sky Cover P_o in April, 12-14 LST, Over Germany

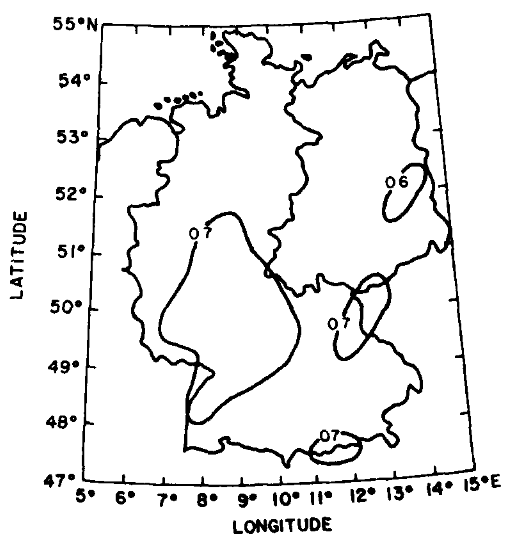


Figure 18h. Mean Sky Cover P_o in April, 18-20 LST, Over Germany

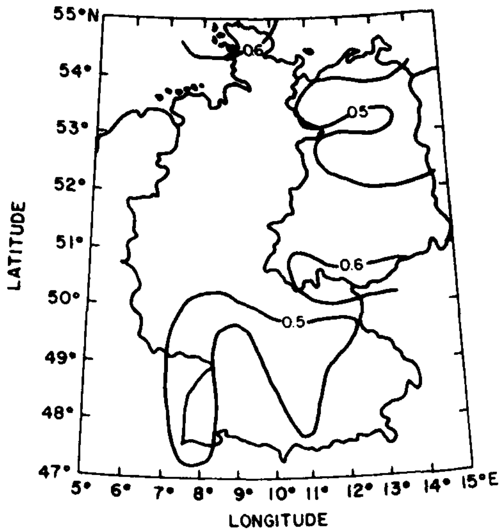


Figure 18i. Mean Sky Cover P_o in July, 00-02 LST, Over Germany

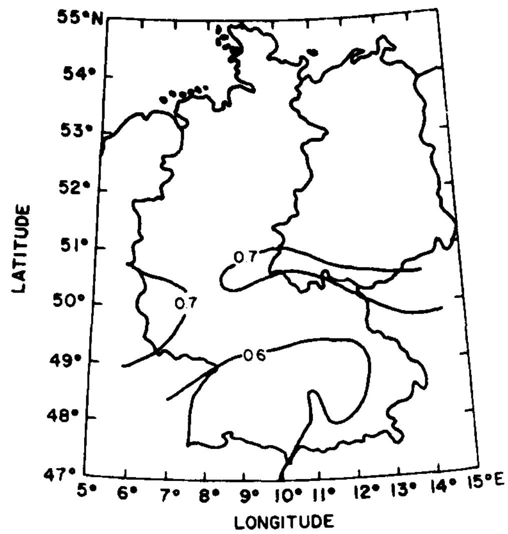


Figure 18j. Mean Sky Cover P_o in July, 06-08 LST, Over Germany

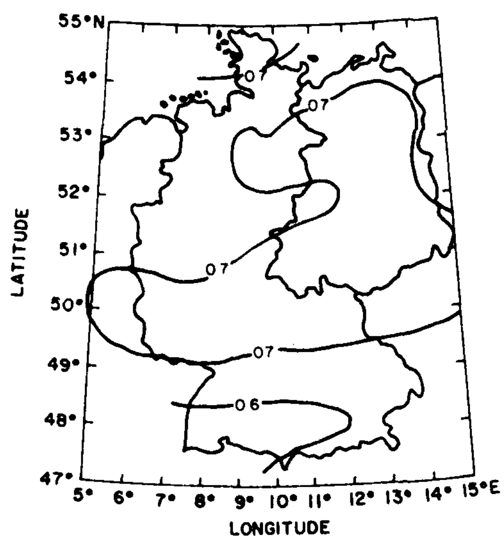


Figure 18k. Mean Sky Cover P_o in July, 12-14 LST, Over Germany

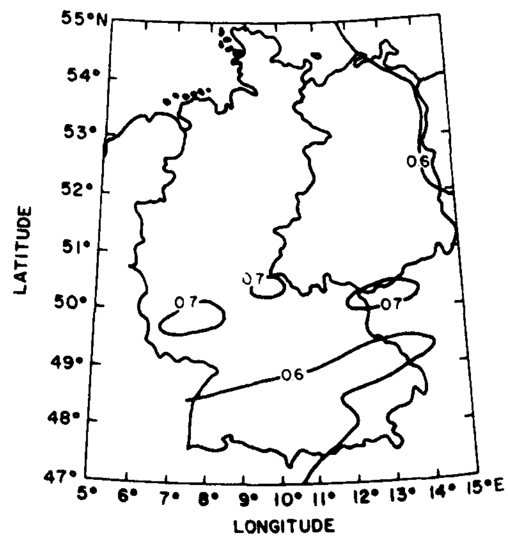


Figure 18l. Mean Sky Cover P_o in July, 18-20 LST, Over Germany

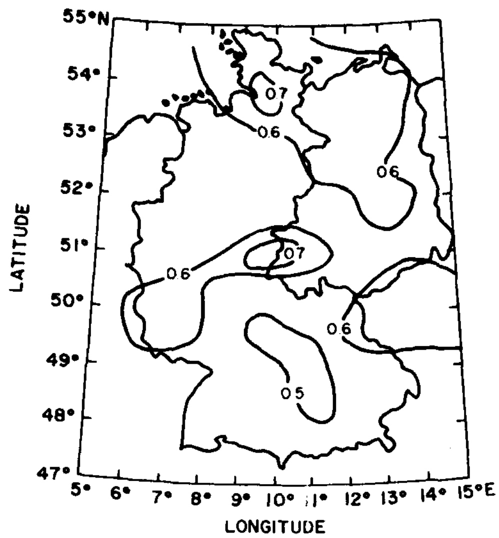


Figure 18m. Mean Sky Cover P_o in October, 00-02 LST, Over Germany

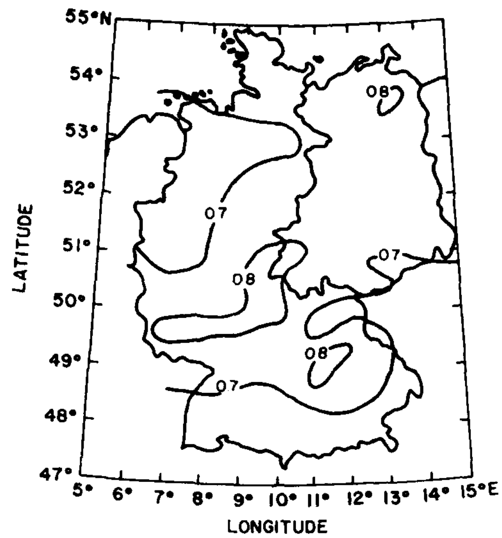


Figure 18n. Mean Sky Cover P_o in October, 06-08 LST, Over Germany

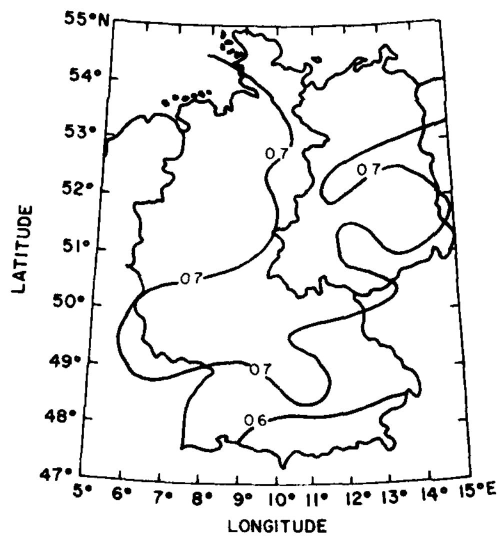


Figure 18o. Mean Sky Cover P_o in October, 12-14 LST, Over Germany

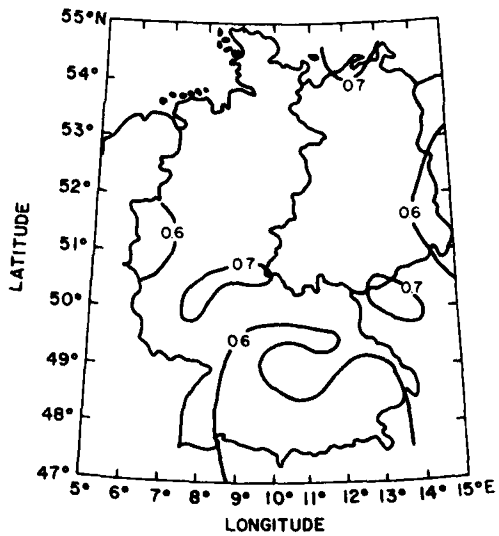


Figure 18p. Mean Sky Cover P_o in October, 18-20 LST, Over Germany

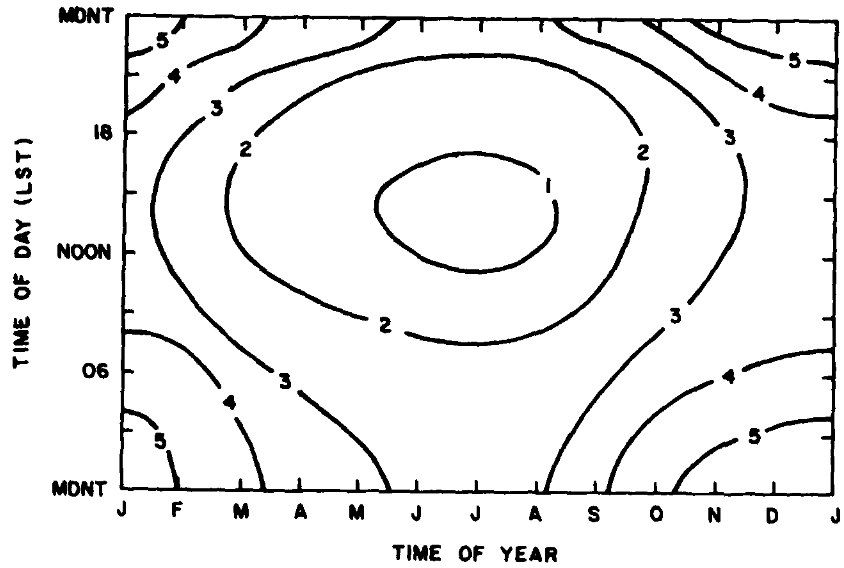


Figure 19. Analysis Over All Time Periods of the Average Values of the Scale Distance r for the German Stations

eastern United States, with peaks ranging from 600 to 1200 m. Elevations of the stations used for the SLM and for calculating r (Nos. 1-28 and 51-64, in Table 3), ranged from 1 to 720 m. The true Alpine region, with peaks generally over 1500 m and some as high as 2962 m, is located in a very small area across the southern border of West Germany, and was not captured by these data.

Also unlike the Korean study, no simple patterns have emerged from the German results to indicate geographic relationships of any sort. For the SLM, parameters a and b, as analyzed in Figures 16 and 17, show quite a number of "jumbled" patterns, with no two quite alike. Figures 16b, 16c, 16g, 16k, and 16o are a few examples of maps that could have been subjectively analyzed many different ways. Since many analyses in Figures 16 and 17 show the tightest gradients in the central region, one might surmise that this indicates the effect of topography, as that is a hilly region. These gradients, on the other hand, might simply reflect the greater concentration of data points in this region. A pilot study was conducted prior to the development of the SLM to point out the relationships that exist between topography and total cloud cover climatology. Percentage frequencies of clear ($x \leq 0.05$) and overcast ($x \geq 0.95$) conditions, as well as P_o, were compared to elevation, slope of terrain, and average elevation surrounding the station. While no relationships were found, the results must be termed inconclusive.

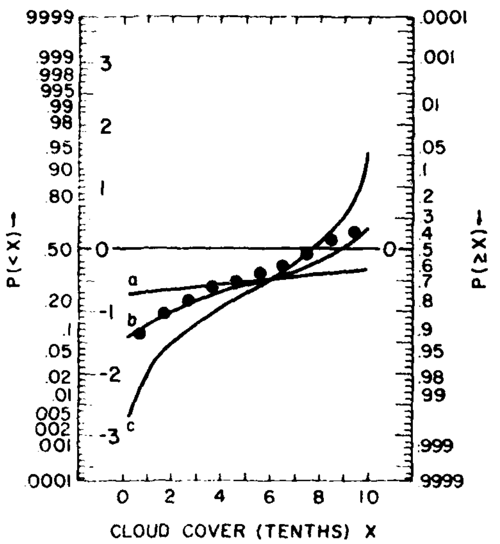
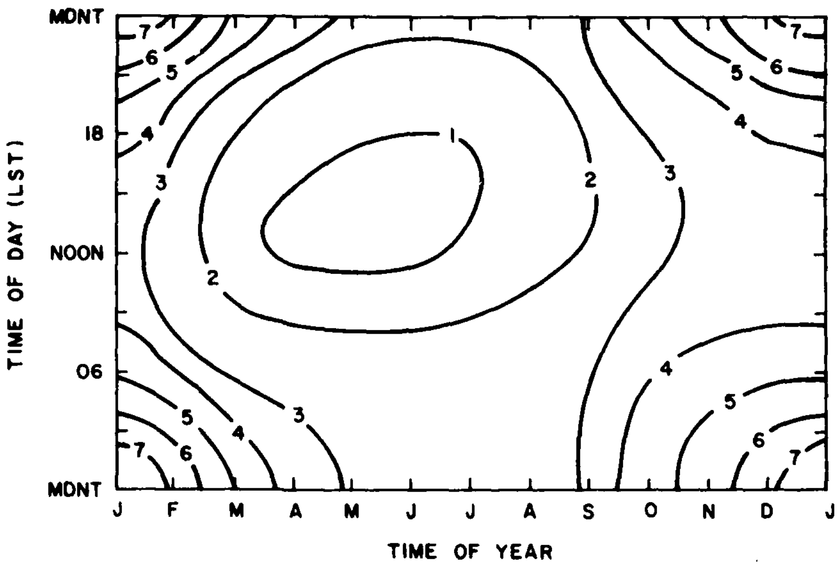


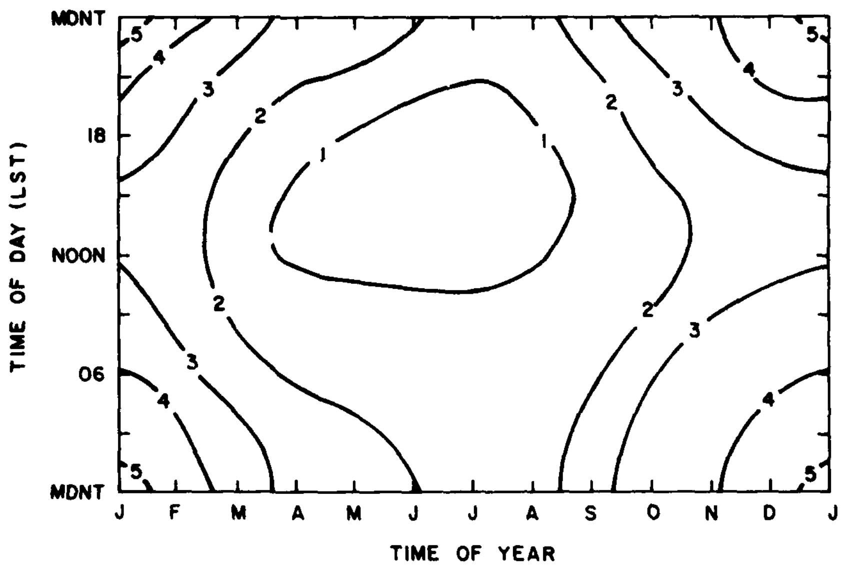
Figure 20. Model B Cumulative Probability Estimates of Fractional Cloud Cover at Heidelberg, West Germany, During April, 18-20 LST for Areal Coverages of (a) 1 Percent of the Observer's Field of View (24 km^2), (b) The Observer's Field of View (2424 km^2) and (c) Ten Times the Observer's Field of View (24,240 km^2) Compared With Data. The dots represent the data values

Model B results show practically no gradients in the r values, and a very flat pattern in the P_0 analyses (Figure 18). Because of this, a chart was constructed of the average values of r analyzed as a function of time of day and year (Figure 19). That this chart is representative of all the stations is supported by comparing it with a similar chart from the station with the largest annual mean r (Nürnberg, Figure 21a) and the station with the smallest (Rhein-Main, Figure 21b). An experiment to determine the climatological frequencies of total cloud cover using the average values of r in Figure 19 gave favorable results. For eight stations, rms errors averaged between 0.03 and 0.05. Thus, r appears to be affected little by the terrain of central Germany. To apply this conclusion to the Alpine region further south would be ill advised since data from that area were not available.

Caution is advised in interpreting these results. It is not being said that terrain has no effect whatsoever on the cloud patterns of central Germany. That the operational forecaster must consider terrain when making his daily weather reports



(a) Nürnberg



(b) Rhein-Main

Figure 21. Analysis Over All Time Periods of the Scale Distance (r) for the German Station With the (a) Largest Annual Mean r (Nürnberg) and (b) The Smallest Annual Mean r (Rhein-Main)

is not doubted. However, the forecaster is concerned about the highly localized effects of terrain on different cloud levels (some levels are more affected by terrain than others) and on a day-to-day basis. In this report the concern is with the climatology of total cloud cover, using a data network that, while in the mesoscale range, is still too coarse to pick up the local effects. Undoubtedly, the tendency of climatology and total cloud cover is to smooth out the daily terrain-related variations of different levels of cloud cover. For the purposes of the current study, then, the Central German topography does not play an important role in the application of Model B in that area, and terrain effects on the SLM in that same region are, at best, inconclusive at this time.

While the German SLM results are not as good as the Korean figures, they still show that the linear model is workable in Germany. As discussed in the section on Korea, Model B is appropriate when areas different from the observer's field of view are involved.

3.5 Comparison of the Simplified Linear Model With the Johnson S_B Model

As mentioned in the introduction, several other models already exist that describe the climatological frequency of total cloud cover. A comparison of the SLM with one of these models, the Johnson S_B curve, is summarized in Table 8. The worst, average, and best cases from the SLM for both Korea and Germany (see Tables 5 and 7) are presented. In Korea, the SLM does better on average, with smaller rms errors for the best and average cases. The differences are small, however. For Germany, the S_B curve does better on average, but again, the difference is small.

3.6 Applications of a Previous Mesoscale Study

The process of modeling a meteorological variable and relating the model parameters to physical features to obtain climatological information in data void regions has already been tried for visibility by Somerville and Bean.[9] The results of that study will now be analyzed briefly and applications made to the current work.

Somerville modeled the probability estimates of visibility by fitting the Weibull distribution as follows

$$F(x) = 1 - e^{-\alpha x^{\beta}} \tag{14}$$

9. Somerville, P.N., and Bean, S.J. (1981) Modeling Visibility for Locations in Germany Where No Records Exist, Final Report, Contract No. F19628-80-C-0004. University of Central Florida, Orlando, Florida, AFGL-TR-81-0313, AD A111890.

Table 8. Comparison of the Simplified Linear Model With the Johnson S_B Model for the Worst, Average, and Best Cases From the Simplified Linear Model Study for Both Korea and Germany

Station	Time (LST)	Case	ρ^2 S_B Model	ρ^2 Linear Model	ρ^2 Difference (S_B-linear)	rmse S_B Model	rmse Linear Model	rmse Difference (S_B-linear)
Chinhae	Jul, 12-14	worst	0.988	0.955	0.033	0.019	0.022	-0.003
Kangnung	Jan, 18-20	average	0.976	0.988	-0.012	0.015	0.012	0.003
Chunchon	Jan, 18-20	best	0.980	0.998	-0.018	0.015	0.005	0.010
					Average	0.016	0.013	0.003
Hannover	Jan, 12-14	worst	0.908	0.834	0.074	0.055	0.075	-0.020
Dresden	Oct, 18-20	average	0.994	0.962	0.032	0.011	0.027	-0.016
Heidelberg	Jan, 00-02	best	0.976	0.998	-0.022	0.012	0.004	0.008
					Average	0.026	0.035	-0.009

where x is the visibility in statute miles and F(x) is the cumulative probability of the visibility equal to, or less than, x miles. The parameters α and β varied, for an average station in Germany, with month and time of day, within the limits

$$0.0011 \le \alpha \le 0.322$$

$$0.678 \le \beta \le 2.53 \quad .$$

It was found that the parameters varied with physical features. Using 30 stations in the southern half of West Germany, 96 pairs of equations were determined for estimating α and β [12 months of the year, 8 periods of the day (00-02, 03-05, . . . , 21-23 LST)]. Using these equations to estimate the probability of the visibility at the same 30 stations for all time periods resulted in rms error values ranging from 0.009 to 0.091.

Taking the case with the smallest rms error as an example (0.009 for July, for 15-17 LST), the equations for α and β are

$$\alpha = 0.001663 - 0.0006203x_1 + 0.00001414x_2 - 0.0002829x_3 + 0.001416x_4$$

$$\beta = 1.934 + 0.002504x_2 \quad , \tag{15}$$

where

$$x_1 = (EL^3/10^9) \cdot (MP^3/10^3)$$
$$x_2 = (EL^3/10^9) \cdot (WN^3/10)$$
$$x_3 = (EL^3/10^9) \cdot (EL/AE)^2$$
$$x_4 = (MP^3/10^3) \cdot (WN^3/10)$$

and

EL is the elevation of the location (ft)
MP is the mean precipitation (in.) for the month
WN is the mean windspeed (kt) for the month
AE is the average elevation (ft) of the 20-km radius circle surrounding the selected location.

Some effects of these influences (EL, MP, WN, AE) on the probability of visibility thresholds are shown in Table 9. As computed, the effect of rain is to reduce visibility. The effect of increasing windspeed is to reduce visibility, the effect increasing with increasing elevation. The effect of elevation is to improve visibility somewhat when the windspeed is less than 2-1/2 m/sec, but to increase the

Table 9. Estimates by the Weibull Distribution of the Probability of Visibility Less Than 10 Miles, When the Parameters α and β Are Obtained by Somerville's Equations, Incorporating the Influences of Terrain, Rainfall and Windspeed. The equations are for July, 15-17 LST

Station Elevation (ft)	Mean Monthly Precipitation (in.)	Mean Monthly Windspeed (kt)	Surrounding Elevation (ft)	Resulting P_{vis} (< 10 mi.)
Rainfall Effect				
1000	2	10	1000	0.45
	3			0.64
	4			0.84
	5			0.96
Windspeed Effect				
350	3	5	350	0.17
		10		0.39
		15		0.75
1000	3	5	1000	0.17
		10		0.64
		15		0.999+
Elevation Effect				
350	3	3	350	0.14
1000			1000	0.12
1500			1500	0.08
350	3	10	350	0.39
1000			1000	0.64
1500			1500	0.996
2000			2000	0.999+
In-the-Valley Effect				
350	3	10	350	0.39
			1000	0.39
			1500	0.39
1000	3	10	1000	0.64
			1500	0.64
1500	3	10	1500	0.996
			2000	0.997
Mountain-Top Effect				
1000	3	10	1000	0.64
			350	0.50
1500	3	10	1500	0.996
			1000	0.992

restriction when windspeed is greater than 2-1/2 m/sec. In-the-valley effects are small or nonexistent. The mountain-top effect is to improve visibility somewhat with increased mountain height.

The above exercise gives an indication of the considerable effort that is required to find working relations to yield probabilities of a variable such as visibility in terms of other variables. Topographic information must be obtained and analyzed in detail at each data point, and a large number of equations must be developed. When applying the model, this detailed topographic information must then be found at each point for which a solution is desired. The topographical features almost never appear by themselves in the Somerville equations, but instead in combination with one of the meteorological variables. Apparently, additional meteorological information is needed to make the topographic variables useful. However, there seems to be little advantage in estimating visibility in terms of other meteorological variables such as precipitation and windspeed which themselves will need to be surmised in data-void regions. Furthermore, incorporation of topographic effects may make the model suitable for that specific region of the world, but one should hesitate to apply the equations elsewhere. Since mesoscale effects are highly localized, a study completed in one geographic area generally will not be applicable to another area. The visibility model here, for example, did poorly when tried in several other regions of the world.

Thus, mesoscale climatological modeling that incorporates terrain features in an effort to obtain information in data-void regions is highly complex and quite regional in nature. As an alternative, interpolating model parameters from maps similar to the ones shown in this report (for example, Figure 6) might be more feasible. Interpolation could be done subjectively or by computer. The accuracy of the maps would, of course, depend to a large extent on the density of data coverage. With this method the desired climatological information could be obtained at any point within the region studied provided the model applies and provided data is available from which the initial analysis can be made. This method is, of course, easier to work with both in the developmental stage and user stage since fewer equations are involved and less information is needed.

4. CONCLUSIONS

Results of a study of mesoscale cloud cover over Korea and Germany, undertaken to obtain cloud climatologies in data-void regions, have been presented. Two methods for modeling the climatological frequency distribution of total cloud cover were presented and discussed. One model was a simple linear regression called the Simplified Linear Model (SLM), the other was Gringorten's Model B.

The SLM was used successfully to describe the cumulative frequency of total cloud cover for data from stations in South Korea and Germany. Model parameters a and b (slope and y-intercept) were plotted and subjectively analyzed. Although Korean data were sparse, analyses suggested the existence of mesoscale geographic influences on the model parameters which could enable the development of methods for obtaining a and b and thus the cloud cover frequency at locations where there are no data. A denser network of data is needed to complete such a study. The German data, though more numerous, did not reveal any simple relationships with geography.

One advantage of this model over other models is its simplicity, both in development and use. Another advantage is that it yields finite probabilities of all clear and full overcast, as opposed to other models which yield only zero probabilities for clear and overcast, and hence cannot be theoretically accurate. One such model is the Johnson S_B curve. A comparison of results of this model with the SLM showed only slight differences between the two. Both had favorable results. Therefore, since the SLM is well behaved at the important clear and overcast categories, and since it is slightly simpler to use, it is definitely the favored model. This argument holds even more sway when considering the other models since they are even more complex than the Johnson S_B model.

Model B was also used successfully to describe the cumulative frequency of total cloud cover. Subjective analyses of P_o and r showed definite mesoscale geographic patterns in Korea, but none to speak of in Germany. In fact, the German analysis of r was so flat, area averaged values were used in an eight station sample for each time period, with good results. Thus, r is affected little by the terrain of central Germany.

Model B, like the SLM is also well behaved at clear and overcast, giving it a distinct advantage over other models. However, there is no exact mathematical formula for this model, since it was derived by Monte Carlo simulation, and it is more complex than the SLM. Therefore, at least in the Korean and German areas where results of the two models were similar, the SLM would be the preferred method. The one major exception is when the sky cover climatology is desired for areas other than that of the observer's field of view. In those cases, Model B is superior to all others, since it is the only model that can handle such a situation.

The analysis of a previous mesoscale study of visibility indicated that considerable effort is required to find mathematical relations between a meteorological variable and mesoscale geophysical features for the purpose of obtaining climatologies in data-void regions. Such a method is extremely complex, using many equations and needing precise topographic information of all data points and

at all points where climatologies must be developed. Unfortunately, such a method is also highly localized. An alternative method was presented, that of interpolating the model parameters from map analyses. This scheme is much easier to work with and still gives model parameters at any point in the region studied.

One must be careful to note, especially in the case of the SLM, that this investigation applies solely to two small (but militarily significant) areas of the globe. It is not known over what extent of the globe the models are applicable. Future work should include the testing of these models in different regions as well as further testing in Korea and Germany with a larger sample size.

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